A LABORATORY AND FIELD GUIDE TO BIOLOGY

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A LABORATORY AND FIELD GUIDE TO BIOLOGY

BY

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To

the numerous assistants and hundreds of enthusiastic students with whom the writer has worked at the University of Pittsburgh, this volume is dedicated on the one hundred and fiftieth anniversary of the University.

PREFACE

This guide is designed to direct the student in the study of living organisms. It was written to provide a working method for Nature Study, Field Biology, and General Biology. The program of studies outlined here is obviously for Natural History courses. It is the opinion of the writer that the cultural courses in Biology should be of this type, instead of the usual dissection courses which are primarily pre-professional in character.

A survey of General Biology reveals a wide variety of courses in the various institutions in which it is offered, usually, as a first year course. The vast scope of the subject, combined with the fact that each instructor has his own ideas of selection and organization of material, have resulted in a diversity of equally good courses. The majority of these are, more or less, type courses in which preserved specimens are used and in which an emphasis is placed upon anatomical details. Such courses serve admirably in the training of students who plan to major in some special phase of biology—either plant or animal—students who are definitely preparing for medicine, dentistry, or biological research. The thousands of non-professional students, however, who select biology as a cultural subject find little interest in the lifeless specimens which they dissect or in the involved principles of structural organization which, after all, are and should be of interest to a comparative few. After nearly twenty years spent in teaching pre-professional courses, the writer firmly believes that such courses should be open only to the students for whom they were and are designed.

America has become Nature minded and the present aims in the widespread teaching of biology are primarily to develop an understanding of and an interest in the world about us. Biology for

the masses should supply a wholesome recreation; it should assist in the solution of the problems of the leisure hour; and it should contribute to intellectual happiness. The myriads of organisms, plant and animal, in the immediate environment of every individual; or the relationships between and among these; and their bearing on the welfare of humans could not possibly be incorporated in the "type and principle" course.

The scene of biological observations for the vast majority of the students who do take the biology course will not be in a laboratory but rather along city streets, in back yards, and in vacation centers.

There is an almost universal agreement on the aims set forth. There are some, however, who will doubt the possibility of their achievement. The writer firmly believes, through his own experiences, that these ends can be attained. He is thoroughly convinced that the general course can offer a background adequate for developing an interest in the biotic environment and an interpretative ability that will lead to an understanding and esthetic appreciation of the living world. It is hoped that there will be enough adventurous souls who will wholeheartedly endeavor to substantiate the proposed possibilities of biological training.

If this is accomplished, biology will have a new meaning; it will exert a greater influence; and it will assume a prominent place among the humanities in its contribution to better living.

In presenting this course, the writer fully realizes its departure from the older ideas of the first year course. In it the teacher's work will be considerably increased. It will require greater planning and closer direction, for a time. In many instances it will require an expanded training, but in the hands of a skillful teacher the growth and fascination of the subject can be deliberately developed.

New problems such as scheduling field work, finding available situations, providing transportation, and securing the necessary working library will present themselves. But will not the end justify the effort?

If the present-day popularity of biology in secondary schools and colleges is to be sustained, the course will have to be revised to include more of the natural history point of view.

This guide is a revision and elaboration of the writer's *Systematic Guide to Field Zoölogy*, which he has used for eight years. It offers ample opportunity for modifications which because of the local situation or conditions may seem to the teacher to be of value. It is intended primarily to suggest a method and a point of view. Its publication is in response to numerous requests for a working guide which were received upon the publication of the author's text, *The Living World* (The Macmillan Company, 1937).

As usual, the writer had to depend upon others for assistance and he is grateful to Mr. Lee W. Henderson, Jr., his assistant in the course, for his willingness to type manuscript and read proof.

The writer will always feel grateful to the various persons who, early in his life and training, developed in him an absorbing interest in the wonders of nature. Among these are: Mr. George W. Gordon; Dr. Paul R. Stewart, now President of Waynesburg College; Dr. Hugo Kahl, Curator of Entomology in the Carnegie Museum and Advisory Professor of Zoölogy in the University of Pittsburgh; the late Dr. Arnold E. Ortmann, Curator of Invertebrate Zoölogy in the Carnegie Museum and Professor of Zoölogy in the University of Pittsburgh; the late Dr. W. J. Holland, for many years Chancellor of the University of Pittsburgh and Director of the Carnegie Museum; Dr. O. E. Jennings, Head of the Biology Department at the University of Pittsburgh and Curator of Botany at the Carnegie Museum; Professor Dr. Ferdinand Pax at the University of Breslau; and in recent years Doctor John G. Bowman, Chancellor of the University of Pittsburgh, whose ability to see and interpret the poetic beauty in nature has been a constant source of inspiration.

SAMUEL H. WILLIAMS

PITTSBURGH, PA.
April, 1938

FOREWORD

It is understood that every course need not necessarily include all of the suggestions incorporated in this outline. There is also room for more detailed studies than are here prescribed. A course should be flexible enough to allow the introduction of local material, as well as original ideas of the teacher. Not all of the situations listed here will be found in any section but the list of exercises is diverse enough to provide ample material for any course. Some of the exercises will require considerable time. The topical suggestions should point the way toward a comprehensive concept of nature as a whole with an interpretation of all of the involved principles of survival designated in the various exercises.

It is obvious that no single text could include all of the details of structure of plant and animal groups. Elementary texts, guides and manuals will be necessary in identification studies. Because of the extensive bibliographies in the text, it was thought unnecessary to include them here. Used with *The Living World,* this laboratory guide should be very practical.

The sequence of the association exercises need not be followed and the teacher should feel free to modify procedure as seasons and local conditions demand. In every case, the exercise should be read and discussed thoroughly before the study is initiated.

If time permits, exercises on the fundamentals of Mendelian Inheritance should be given. It is also desirable to allow each student to select a larger vertebrate such as a rabbit, pigeon, or serpent, for dissection.

The Reports at the ends of the exercises are designed to stimulate closer observation and to develop the investigative habit. One or more of the questions in the report should be assigned to each student. Class discussion should follow.

EQUIPMENT AND METHODS

General Laboratory Equipment. Microscopes, binocular magnifiers, microscope slides and cover glasses, dip nets, tow nets, plancton nets and sorters, mason or amerseal jars, battery jars, aquarium tanks of various sizes, pipettes, bottom scrapers, insect boxes, riker mounts, insect pins, spreading boards, insect labels, wire strainers, glass vials of various sizes, scissors, canada balsam, white shellac, glue, glycerine, cyanide, carbon tetrachloride, naphthaline crystals, alcohol, chloretone, carbon bisulfide, paradichlorobenzene, Lamotte indicator set for hydrogen ion determinations, breeding cages, hand axe and geologist's pick.

Nets, insect boxes, and aquarium tanks can be made by the students.

Student's Materials. Insect net, three killing jars, homeopathic and other vials, jars, insect pins, small field notebook, india ink, artist's pens, small camel's hair brush, carrying case, hand lens, fine pointed forceps and insect boxes. A pair of field glasses is desirable for bird studies.

Killing bottles can be made by placing a thin layer of plaster of Paris on the bottom of jars and bottles. Add potassium or sodium cyanide and cover this with another thin layer of dry plaster of Paris. Make a thick paste of plaster of Paris and place this over the three layers in the jars. Set the uncovered jars in a safe place outdoors until dry. Three or four hours should suffice in warm weather. Cyanide is poisonous and the jar should be so labelled. A non-poisonous killing jar can be made by soaking sawdust or cotton in carbon tetrachloride and packing it in the bottom of a

jar. A disc of cardboard can be placed over the sawdust to hold it in place.

Collecting and Preserving. A good collector proceeds slowly and investigates each situation thoroughly. Examine the stem, leaves, flowers, and fruit of plants. Look in every crevice, in burrows, under logs and stones on the ground. Tear off loose bark on dead recumbent logs and stumps and carefully examine the bark and the surface of the log; then examine the wood. Hold the open net or opened umbrellas underneath shrubs and saplings and shake them violently. Sweep the net back and forth among the low grasses and herbaceous plants. Empty the contents of the net into a killing jar.

Do not overlook the minute animals such as aphids, lice, mites, and small spiders. Tracks, excrement, and other evidences of unseen inhabitants and visitors should be studied also. Pupae, cocoons, egg masses, and exuviae are important.

When a butterfly or moth is captured in the net, it should be pinched at the bases of the wings before it is placed in the killing jar. Do not handle the wings of moths and butterflies with the fingers. When flying insects of all kinds are caught with the net, turn the handle quickly to prevent their escape. Butterflies should be placed in separate killing jars. Beetles, bugs, flies, bees, and dragonflies should never be placed in the jars with butterflies and moths.

Place all soft-bodied specimens, such as wood lice, aphids, larvae, worms, ants, spiders, and pillbugs in vials of preserving solution. Snails, slugs, flatworms, and brightly colored forms should be taken to the laboratory alive and killed as suggested in the chart. Formalin is less likely to destroy color than alcohol. Hot alcohol will not extract color from most forms.

Mounting. Soft-bodied animals such as worms and larvae should be kept in vials of preserving fluid. If a specimen is desired for display, it should be distended and held in place with a background of cotton or white paper.

Beetles should be pinned through the right elytron or wing cover.

Flies, bees, wasps, orthopterans, stoneflies, and mayflies should be pinned through the thorax, a little to the right of the center in the flies.

Bugs should be pinned through the scutellum.

Minute Diptera and Hymenoptera can be mounted on short sections of very fine pins. These can be inserted in pieces of pith which have heavier pins inserted in them.

Small beetles and other minutia can be attached to the points of small triangles of stiff paper. The pin should be inserted through the broad end of the triangle.

Butterflies, moths, dragonflies, and other winged insects should be pinned through the thorax and placed in the groove of a spreading board. The wings can be expanded with the point of a fine pin and held in place with narrow strips of paper until dry.

The label bearing date, locality, and name should be placed beneath the specimen on the pin. For additional details consult the chapter "Methods of Study" in *The Living World.*

COLLECTING CHART

Animal	*Where to Collect*	*How to Keep Alive*	*How to Kill and Preserve*
Protozoa	Pools, ponds, lakes, especially where water plants abound	Keep in dark, cool place	
Freshwater Sponges	Springs, creeks, rivers, attached to stones, sticks, and débris	Must be kept in cool running water	5% formalin will preserve
Hydra	Ponds, lakes and rivers, attached to floating leaves and submerged objects	Place débris in jar. Fill with water and allow to stand uncovered	Kill in hot Bouin's fluid and, after washing, place on slides or in 70% alcohol
Flatworms	Creeks, rapid brooks, and springs, on stones	Place in jar of fresh water. A jar with ground liver placed in water will attract them	Place on glass slide and flood with hot corrosive sublimate solution. Wash and run through alcohols. Mount on slide with balsam
Rotifers	Plants and débris in lakes, ponds, and lagoons	Place débris in jars of fresh water	
Bryozoa	Ponds, stones in brooks and creeks. Attached to stems, rocks, and leaves in streams and ponds	Keep in fresh water for examination before killing	Flood with hot Bouin's or mercuric chloride solution. Large colonies in 15% formalin

Leeches	In weeds and muck in ponds, creeks, and rivers. Attached to other animals and on underside of boats	Keep in fresh water	Place in warm chloretone and preserve in 70% alcohol
Earthworm	Spade up rich soil or collect with flashlight at night on lawns	Keep in rich, moist earth	Place in weak alcohol and add 95% slowly
Crayfishes	Streams, ponds, and creeks, under stones	In tanks or jars of fresh water with gravel on bottom	75% alcohol or 10% formalin
Centipedes	Under logs and stones and under bark of dead logs	Handle with forceps and keep in jar with dead leaves	Carl's solution or 8% formalin or 70% alcohol
Millipedes	Under logs and stones and in rotting logs	In jar with moist earth and dead leaves	Carl's solution or 8% formalin or 70% alcohol
Slugs	On plants, under bark, logs, and stones, in moist places	In wire cages with lettuce or growing plants	Place in hot water and transfer to 80% alcohol
Snails (land)	Under logs and stones and on trees	In wire-covered jars; feed with lettuce	Drown in water with a little magnesium sulfate. Preserve in 70% alcohol to which a few drops of formalin have been added

COLLECTING CHART (*Continued*)

Animal	*Where to Collect*	*How to Keep Alive*	*How to Kill and Preserve*
Water Snails	On stones, stems, and among plants in water	In jars of fresh water	Weak solution magnesium sulfate and transfer to 12% formalin
Mussels	Ponds, creeks, rivers, on the bottom	In aquarium tanks with growing plants and sand bottom	Place wooden wedges between valves and drop into 15% formalin
Water Insects	On surface of ponds and streams and among water plants and débris	In aquarium with wire covering and growing water plants	Dry and pin adults. Nymphs, naiads, and larvae in 70% alcohol
Salamanders	In streams under stones and under stones and logs in damp places	Tanks with rich moist earth and dead leaves. Keep quite moist	Etherize and place in 10% formalin. Inject formalin if possible
Insects	Everywhere on and under water; on plants and in them; on and in the ground; on other animals; flying	In wire cages with growing plants	Kill with potassium cyanide, carbon bisulfide, or carbon tetrachloride. Pin and keep in boxes
Mites and Ticks	On plants; in decaying organic matter; on bodies of animals, including beetles and grasshoppers	Keep living hosts	Place directly in 70% alcohol with few drops of glycerine

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A LABORATORY AND FIELD GUIDE TO BIOLOGY

Exercise I

THE USE OF THE MICROSCOPE

OBJECT: To learn the proper use of the microscope.

DIRECTIONS: Become familiar with the following parts of the compound microscope: ocular, body tube, draw tube, revolving nosepiece, low and high power objectives, coarse and fine adjustments, arm, stage, slide clips, diaphragm, condenser (if one is present), concave and plane sides of the reflecting mirror, inclination joint, and base. Make a drawing of the microscope from the side.

Some rules for microscopic procedure:

1. Keep the lenses clean. Use lens paper only for cleaning.
2. Never touch lenses with the fingers and never get them wet.
3. Do not focus downward. You may ruin the lens and break the slide.
4. When changing from low to high power, lift the body tube first. The high power lens is longer and will strike the slide or stage.
5. Never unscrew or remove parts of the microscope. It is a delicate instrument and an expensive one.

6. When ready to use the microscope, adjust the concave mirror so that the best light comes through the opening in the stage.
7. Keep both eyes open at all times when using the instrument. This will seem awkward at first but it is the best procedure.
8. When examining objects, the amount of light can be regulated by opening or closing the diaphragm.
9. Use high power only on objects under cover glasses.

PROCEDURE: Using some prepared slides, place one on the stage with the object over the opening. Looking from the side, carefully lower the objective until it almost touches the slide. Do not look in the ocular to do this. Keeping both eyes open and looking in the ocular with one eye, slowly raise the body tube with the coarse adjustment until the object on the slide comes into view. After securing the best focus you can with the coarse adjustment, use the fine adjustment until you have a well-defined focus. If the object is off center, take the slide in both index fingers and gently move it around until the object is entirely visible. Large objects cannot be seen completely because the field is limited.

After you have focused the object, call your instructor and let him decide if you have done it properly. If the light is poor or too glaring, move your reflecting mirror until you secure the desired illumination.

Try five or six slides until you feel that you have mastered the the art of focusing.

Raise the body tube and swing the high power objective into place. Looking from the side, lower the objective until it almost touches the slide. Then with both eyes open look into the ocular and very slowly raise the body tube until the object comes into view. Secure a well-defined focus with the fine adjustment.

Swing the low power objective back into place. Take a drop of stagnant water and place it on a microscope slide. Place a cover glass over the drop of water and focus as before by raising the

body tube with the coarse adjustment. Make sure that the moving one-celled organisms are seen clearly, although the depth of the water may allow for sufficient vertical migration to enable them to swim out of focus. If the organisms move too rapidly, introduce a drop of chloretone solution into the water along the edge of the cover glass. This will slow them down. Cotton fiber and glycerine or glycerine jelly will also reduce their rapid movements.

Examine paper, cloth, and insect legs under low power, adjusting the light so as to see all of the details of structure.

REPORT

1. When and by whom was the microscope discovered?
2. Who are some of the men who developed the instrument?
3. What contributions has the microscope made to the betterment of human welfare?
4. How may the magnification of a microscope be determined?
5. What is an oil immersion objective?
6. What is Histology? Cytology?

Exercise II

CELL STRUCTURE AND ONE-CELLED ORGANISMS–PLANT AND ANIMAL

OBJECT: To determine the fundamentals of cell structure and to compare the cells of plants and animals.

DIRECTIONS: Examine slides bearing stained ameba, paramecium, euglena, and volvox. Note the characters of ameba such as: a clear outer region, the ectosarc; and the darker endosarc. Can you with high power determine the nature of the protoplasm surrounding the nucleus which is the central dark structure? The

protoplasm within the nucleus is called nuclearplasm and that around it is the cytoplasm. What are the theories with regard to the physical nature of protoplasm? Observe the food and contractile vacuoles. What are their functions? Is a distinct cell wall present? The extenuations of the body are the pseudopodia or locomotor structures.

Compare the mounted and stained specimen with a living specimen taken from pond water or cultures. Are all regions and structures visible? Note the movement of the protoplasm.

Paramecium is found abundantly in stagnant water or cultures may be made by placing a wisp of hay in a glass of water and keeping this in a warm place for several days—preferably in the dark.

On the paramecium or slipper animalcule note: the shape, two contractile vacuoles surrounded by five, faintly visible radial canals, food vacuoles (variable in number and position), the oral groove, the transparent pellicle composed of hexagonal areas (not distinctly visible), the short, thread-like cilia covering the entire cylindrical body and most dense in the oral groove. Each hexagonal area bears a cilium. Study both live and stained specimens. In the living form observe the movements. Is the rotating movement clockwise or counter-clockwise? Can you see conjugating or dividing animals? The movements of the animal can be slowed down by adding a few drops of chloretone to the water on the slide.

Live euglena may be obtained from ponds and rain barrels. Examine both living and stained specimens. Note: the body shape, the long thread-like flagellum which is locomotory in function, the striated pellicle or cuticle, the pigment spot or eye spot near the top of the body, the reservoirs, vacuoles, small greenish structures containing chlorophyll (chloroplasts or chromatophores), a nucleus.

Examine living and prepared specimens of volvox. Volvox is colonial, the rounded colonies being composed of many individuals

in intimate contact. Note that there are several kinds of cells, viz.: the somatic cells bearing two short flagella and the germ cells or parthenogonidia which may be in different stages of development. Observe the movement of volvox and determine if possible if the individual cells exhibit the characters of the other animals examined. Draw a colony showing the different kinds of members.

Examine a leaf of elodea or ditch weed under the microscope. Note the characters of the cells and the movement of the protoplasm within the cells. Compare with the cells of several other plants such as the scale from an onion bulb, and note the similarities and differences in structures with the animal cells. What do plant cells have that animal cells lack?

Study a prepared section of an onion or hyacinth root-tip. In this the typical plant cell can be studied in detail. You will also see the stages through which a cell passes in reproducing by mitosis. What nuclear changes can be observed? Check the various phases of mitosis in a botany or zoölogy textbook and compare with what you see.

Osmosis is diffusion through the cell membrane and can be observed by mounting a leaf of elodea in water and noting the contact of the cytoplasm with the cell wall. Draw off the water with a blotter and replace the water with a 20% sugar solution, observing the cell carefully. Is water entering or leaving the vacuole? The contracted cell is said to be plasmolyzed. Draw off the sugar solution and add distilled water. Note the changes taking place in the vacuole.

REPORT

1. Make a drawing of a typical cell showing all structures.
2. How does mitosis differ from the binary fission of certain protozoans?
3. What is the Cell Theory and who formulated it?
4. How does the body of a plant or animal grow?

5. What is the function of the contractile vacuole?
6. Describe the nucleus. What happens to it in cell reproduction?
7. Define osmosis and suggest several ways of demonstrating it.
8. To what extent is osmosis employed in the bodies of plants and animals?
9. What factors determine the size to which an ameba can grow?
10. What interrelationships exist between microscopic plants and animals?
11. How does a plant cell differ from an animal cell?
12. Do motile unicellular plants try to escape voracious animals?

Exercise III

FRESH-WATER COELENTERATES— A STUDY OF HYDRA

OBJECT: To become familiar with a common relative of the jellyfish.

DIRECTIONS: Secure some fresh-water hydras from a nearby pond. They are small animals less than an inch in length and may be found attached to stems and débris in the water or on the under sides of lily pads. If débris is collected and placed in jars, the hydras can be observed in a day or two, attached to the walls of the jar. Fresh specimens can always be purchased from supply houses.

Examine a specimen extended, observing the movements of the tentacles. If small crustaceans such as daphnia and cypris are placed in the water, the hydra may be observed in the process of capturing an animal, its serpentine tentacles discharging nematocysts and enveloping the body of its victim. If disturbed the hydra quickly contracts.

Examined under a microscope, the hydra is seen to have two

cell layers surrounding a hollow, tubular body cavity which extends into the tentacles. The mouth is in the center of the whorl of tentacles and is surrounded by a raised portion called the hypostome. Food is digested in the coelenteron or body cavity. On the tentacles, the cnidoblasts or nematocyst-producing cells are numerous and make the tentacles appear lumpy or rough. The outer cell layer or ectoderm is composed of several kinds of cells in addition to the cnidoblasts, and the inner layer or endoderm is almost twice as thick as the outer layer. It too is composed of specialized cells. Cellular differentiation can be observed by the microscopic examination of whole mounts and cross-sections.

Hydra moves about by bending its body until the tentacles are in contact with the substratum and then the base is drawn forward. Reproduction in hydra is usually by budding but occasionally ovaries and spermaries are produced. The spermary or testis is an acute swelling just beneath the tentacles, while the ovary is usually a rather obtuse swelling farther down on the body tube. Hydra has also been known to reproduce by longitudinal fission.

Microhydra, a microscopic jellyfish (medusa), is sometimes found in laboratory aquaria. It has a hydroid stage in its development. There are a few other fresh-water coelenterates but they are rarely seen. For a more minute description of hydra consult a zoölogy textbook.

In nearly all coelenterates the nematocysts are the principal means of defense. They are like invisible poisoned darts which penetrate the bodies of their victims. Large jellyfishes are dangerous to handle.

REPORT

1. Are there any marine phyla which have no fresh-water representatives?
2. What coelenterates are commonly found on the beach and in shallow waters along the ocean shore?

3. Does hydra have a medusa stage in its development?
4. Distinguish between a hydrozoan and a scyphozoan.
5. What is the common method of reproduction in hydra?
6. How is sexual reproduction in hydra effected?
7. Does hydra ever reproduce metagenetically?
8. What coelenterates are colonial?
9. How do jellyfishes swim?
10. What is coral?
11. Why should live jellyfishes never be handled with bare hands?
12. Are all coelenterates diploblastic?
13. Does a coelenterate have a nervous system?
14. What is a statocyst?
15. What cells in the ectoderm enable hydra to contract?
16. How is digestion in hydra effected?
17. How do the cells in the layers of hydra illustrate "division of labor"?

Exercise IV

FLATWORMS (PLATYHELMINTHES)

OBJECT: To become familiar with the principal features of free-living flatworms.

DIRECTIONS: Collect some fresh-water flatworms. They are found on the stones in running water and appear sometimes as round, dark drops of a slimy substance. They are usually on the under sides of stones and other objects in rapid brooks.

Inasmuch as the flatworms as a phylum, Platyhelminthes, present so many distinct advances over the preceding animal groups, it might be well to examine them. Among these advances are: (1) bilateral symmetry, (2) the occurrence of the mesoderm or

third germ layer, (3) a head process, (4) a well-defined nervous system, (5) an excretory system (flame cells and tubules which lead to the exterior through two pores located dorsally back of the head), (6) well-developed, separate reproductive organs, and (7) dorso-ventral symmetry.

The elongations and contractions of the body are made possible by longitudinal and circular muscles. The head shows two eye spots and two ocular lobes. The mouth is located on the ventral side of the body near the middle and is an extensible proboscis surrounded by a muscular pharynx. It leads to a biramous, many-pouched coelenteron or gastral cavity. No anus is present and solid wastes are ejected from the mouth. An invisible genital pore is situated back of the mouth. The body is covered with many minute cilia by means of which locomotion is chiefly effected aided by muscular action. The vibrating cilia produce a disturbance in the water around the animal and for this reason the class is named Turbellaria.

White species of flatworms are rather common. Most of the flatworms are parasitic and they include the flukes and the tapeworms. The life histories of these are often complicated, requiring several hosts. The liver fluke passes through several stages in the body of a water snail. Many tapeworms require dual or multiple hosts for their development. Make a list of the more common ones with their intermediate and ultimate hosts.

Flatworms are easily kept alive in the laboratory by feeding them boiled beef liver. The water should be changed within two hours after feeding. Interesting experiments on regeneration and axial gradients can be performed on living specimens.

The diverse characteristics of the phylum can be further seen by examining slides of the tapeworm (Cestoda) with its head or scolex bearing suckers and hooks, and its segments, strobila, or zoöids of the body. Each segment is essentially an animal with a perfect hermaphroditic reproductive system. Whole mounts of the liver fluke (Trematoda) should also be examined.

REPORT

1. Does cross-fertilization take place in flatworms?
2. How do bisection and regeneration experiments illustrate axial gradients?
3. On what do flatworms feed?
4. Are flatworms monoecious?
5. What differences usually exist between parasitic and free-living flatworms?
6. List the contributions of the flatworms as a phylum to biological advance over preceding groups.
7. Describe the locomotor processes of a free-living flatworm.
8. What are some effects of parasites on their hosts?

Exercise V

THE SEGMENTED WORMS–LEECH AND EARTHWORM (ANNELIDA)

OBJECT: To become familiar with the structure, habits, and habitats of earthworms and leeches.

DIRECTIONS:

I. The earthworm or night crawler is the most commonly used fish bait in America. It is a familiar animal to everyone, but few people are acquainted with its life. Living almost entirely beneath the surface of the ground, its burrows surrounded with the familiar pellets of dirt, the earthworm leads a mysterious existence. After heavy rains earthworms sometimes litter the ground, having been forced out of their flooded burrows. However, at night they frequently come out voluntarily to gather sustenance, usually in the form of leaves which they roll into cylinders and drag into their tunnels.

An examination of the earthworm reveals that its body is composed of rings or segments, more properly called metameres, usually more than one hundred in number. Count the number on the specimen given to you. Note the crescent-shaped mouth on the first body segment which is overhung by the fleshy prostomium. The latter is not a specialized segment. On either side of segment XIV are the pore-like openings of the oviducts (female), and on segment XV the openings of the vasa deferentia (male) indicated by swollen lips can be seen. The openings of the seminal receptacles are minute pores concealed in the grooves between segments IX and X, and X and XI. Surrounding the body from segments XXXI or XXXII to XXXVII a collar or saddle-like structure called the clitellum is distinctly visible. It is not a separate structure but is formed by the swelling of these segments. It functions in reproduction.

Rub your finger along the ventral side of the body and feel the "feet." Examine them with a hand lens and you will see that every segment except the first and last bears four pairs of these bristle-like setae. Note their positions.

The anal aperture is an oval slit in the last segment. Other small openings are present but invisible. Among these are the nephridiopores, a pair of which is located on each segment except the first and last. They are situated ventrally and anterior to the setae. They connect the internal excretory structures (nephridia) with the outside. Dorsal pores are also present, one on each segment from VIII to the posterior end of the body. They connect the body cavity or coelom with the exterior.

If a fresh specimen is used, the body covering or cuticle will be opalescent in the sunlight.

II. Examine a leech and note that its body is also segmented but not so nearly round as that of the earthworm. There are also fewer segments, the number being usually 32.

There is a sucker at each end of the body, the posterior being slightly larger than the anterior. The mouth is located in the

anterior sucker and is provided with three jaws which bear chitinous teeth for biting. An anti-coagulating substance exudes from the mouth to prevent the clotting of the blood of victims attacked. A leech has eleven or more pairs of pouches in its crop. In these enough blood may be stored to last almost a year. The anus is at the posterior end of the body. Leeches are hermaphroditic and the young in most species remain attached to the underside of the parent for some time.

Leeches are usually found in the water attached to animals (fish, frogs, etc.) or stones and other objects. Small transparent annelids are also found in ponds.

REPORT

1. What are the classes of annelid worms? Where are they found?
2. Are any annelids other than leeches parasitic?
3. Are earthworms destructive? Are they beneficial?
4. How does an earthworm see?
5. Are all annelids hermaphroditic?
6. Is an earthworm both hermaphroditic and monoecious?
7. Do earthworms swallow earth?
8. Where are the cocoons of earthworms placed?
9. What common annelids are found in ponds and streams?
10. Does it ever rain earthworms?
11. Do earthworms live in sandy soil, clay, or in soil rich in humus?
12. Are the setae movable?
13. Does an earthworm push or pull itself along?
14. Suggest the origin of metamerism.
15. How does a metamere differ from the segment of a tapeworm?

Exercise VI

A COMPARISON OF A CATERPILLAR AND A WORM

OBJECT: To learn the distinction between the larva of an insect and a worm.

DIRECTIONS: The word "worm" is generally applied to many insect larvae such as tomato worm, cabbage worm, tobacco worm, mealworm, etc. The student of biology should know the difference.

I. Examine the caterpillar of any moth or butterfly. A "cabbage worm" will serve very well, although a hairy form should also be studied. How many body segments are there? How does this number compare with that of the earthworm? Is there a distinct head? Are there eyes present? Compound? Simple? Are there eyes on the worm? Note the pores along the sides. These are the spiracles or openings of the respiratory tract. Are they present on the earthworm?

Note the fleshy prolegs, anterior and posterior. How many are there? Where are they located? Are they segmented or jointed? Are they true legs? How do they compare with the setae on the earthworm?

Are there any tentacles or antennae? Do you observe any other structures not possessed by worms? (It all depends upon the species used as to what other structures are present. Eye spots, hairs, spines, horns, tubercles, scent glands, and hidden structures that protrude when disturbed are frequently found on caterpillars of different kinds. See chapter on Defense and the description of the larvae in *The Living World.*)

Examine specimens or pictures of caterpillars of the royal walnut moth, Cecropia moth, Io moth, monarch butterfly, black swallowtail butterfly, and the woolly bear. Compare the worm

with the legless larvae of ants or bees and with the maggot of the fly.

In the forms of larvae examined is there a distinct coloration not evident in the earthworm?

II. Compare the caterpillar with a dobson fly larva, beetle larva, and a stonefly nymph or naiad. Are these wormlike?

REPORT

1. What are the types of insect larvae?
2. Name several true worms commonly found.
3. Do any native worms have heads, eyes, and legs?
4. Does a worm have a greater or a lesser number of body segments than a larva?
5. Make a list of insect larvae that are commonly called worms.
6. What are tent caterpillars?
7. What do apple worms, tomato worms, wireworms, grubworms, and mealworms grow up to be?
8. What are horsehair worms?

Exercise VII

MOLLUSKS

OBJECT: To observe the general characters of native mollusks and to interpret their life processes.

DIRECTIONS: Secure a slug, a land snail, a water snail, and a fresh-water mussel. Preserved specimens will do. How do they resemble each other? What characters have they in common? In what respects do they differ?

I. *The Mussel.* Check the characters of the mussel in the text and observe the following structures: (1) the two halves or valves of the shell; (2) the concentric lines of growth; (3) the swollen umbo near which the shell is hinged; (4) the smaller dorsal or excurrent siphon; (5) the larger ventral or inhalent siphon; (6) the rough margin of the shell which is really the edge of the mantle. Open the shell and note: (7) the mantle which covers the body (the mantle secretes the shell). Lift the mantle and observe the muscular foot (8) at the anterior end of the body by means of which the animal is pushed along. The lamellated gills (9) are beneath the mantle. How many are there? Remove the body of the mussel and observe (10) the attachments of the anterior and posterior retractor and adductor muscles which open and close the shell. Note (11) the interior pearly (nacreous) lining of the shell. Break the shell and determine the middle layer (prismatic layer) and the outer covering (periostracum).

II. *The Snail.* Examine the shell of the snail and note that it is univalvular and coiled, either to the left or right. Consult your text and locate the following: (1) apex; (2) spire; (3) operculum (if present); (4) aperture; (5) lip; (6) umbilicus; (7) suture; (8) columella.

Place the snail in hot water until the body is extended and note (1) the head bearing tentacles. How many pairs? Note also: (2) the muscular foot on which the animal travels; (3) the pneumostome or breathing pore on the side back of the head; (4) the mouth below which is the radula or lingual ribbon.

As a water snail crawls about on the sides of an aquarium, the muscular foot, the chitinous jaws, and the rasp-like radula can be seen distinctly.

Compare snails of as many families as possible, including the limpets, in order to fix the family characters.

III. *The Slug.* A slug is essentially a snail without a shell. It has a head, tentacles, muscular foot, eyes, and a mantle. How many tentacles are there? Are they of equal size? Look for the

eyes on the tips of one pair. Does the mantle cover the body? Can you find the hidden rudiments of a shell? Where is the breathing pore?

Check the characters of these mollusks against other native species in the classification of animals in the text.

REPORT

1. Are all of the mollusks egg-laying?
2. Are all snails and slugs herbivorous?
3. Where do mussels lay their eggs?
4. Do all snails have a breathing pore?
5. Make a list of the common families of land and water snails.
6. Make a list of the common fresh-water mussels.
7. Make a diagram showing the passage of food through the body of a clam or mussel.
8. Show by diagram the principal features of the nervous system in a clam or mussel.
9. What is the normal position of a mussel in a stream?
10. Diagram the parasitic larva or glochidium of a mussel.
11. How is the distribution of mussels effected?
12. Of what commercial importance are mussels?
13. Are fresh-water mussels edible?
14. Do mussels construct pearls?
15. Are land snails and slugs ever destructive?
16. What is the name of the edible snail sold in markets?
17. Are snails bilaterally symmetrical?
18. Where does the mucus secreted by snails and slugs come from?
19. What marine animals are mollusks?

Exercise VIII

THE CRAYFISH—A STUDY IN ADAPTIVE RADIATION

OBJECT: To observe the principles of adaptation as illustrated by the modified appendages of the crayfish and to become acquainted with their vital phenomena.

DIRECTIONS: The crayfishes comprise an interesting group of crustaceans with diverse habits. Too frequently they are merely found or dissected without regard to the biotic principles which govern their existence, structural adaptations, and habits.

The crayfish lives usually in running water, although some forms inhabit rather stagnant ponds, while still others seek isolation in burrows in mud flats where mud chimneys make their places of abode conspicuous. Crayfishes are nocturnal in their habits and they may be found during the day under stones in running streams. Here they rest in a depression, safe from the current and from the eyes of enemies, with their pincers in a defensive position and with their antennae projected so as to detect the approach of danger. When disturbed they back away from their disturber so as to keep all of their sensory and defense mechanisms in a position of greatest usefulness. Their stalked eyes are extended, the antennae and antennules raised, their pincers ready for use and their bodies raised on their crawling legs, ready for a sudden backward dart with their swimmerets.

Before attempting to determine the morphological adaptations of appendages, it would be best to study a live animal, paying attention to its predatory and defense attitudes, capturing and eating food, walking and swimming, use of stalked eyes, burrowing, and breathing. The latter may be observed by drawing a glass tube and bending it slightly toward a right angle at one end. Fill the tube with colored water (eosin in water or even fine sawdust

in water) and hold the curved end of the tube under the side of the animal back of the cephalothorax. In this way the course of the water over the gills may be distinctly observed. Beginning at the mouth examine all of the twenty pairs of appendages. Determine as far as possible the structural adaptations of all of these. Note the following: small, hollow, whitish, cup-like structures on the basal segment of the antennules. These are the statocysts or balancing organs. Examine the inside with a magnifier and observe the hairs which hold grains of sand—these are the statoliths. Examine the first and second pairs of swimmerets or pleopods. Are they modified? Is your specimen a male or female? Compare it with others in the class. Note the following structures and indicate which are biramous:

- **Appendages of the Head**
  - Stalked eyes, Antennae, Antennules — sensory
  - Mandibles, 1st and 2d Maxillae — feeding
- **Appendages of the Thorax**
  - 1st Maxillipeds, 2nd Maxillipeds, 3rd Maxillipeds — feeding
  - Chelipeds (pincers) — defensive, grasping
  - 1st walking legs, 2nd walking legs, 3rd walking legs, 4th walking legs — walking—the 1st and 2nd also for grasping
- **Appendages of the Abdomen**
  - 1st swimmerets — modified (elongated) in male for copulation and reduced in female
  - 2nd swimmerets — typical in female, copulatory in male
  - 3rd, 4th, 5th, swimmerets and tail (uropods and telson) — swimming

Draw the crayfish from above, showing all of the appendages on one side. Make a drawing of the under side of the abdomen showing the swimmerets. Draw a leg showing exo- and endopodites and the basal protopodite.

Carefully detach all appendages including mouthparts and arrange them serially on a card, gluing them in proper order to the cardboard. Label each structure.

REPORT

1. What activities have you observed?
2. What appendanges were used in the above activities and how?
3. Does the structure of each appendage seem to be well fitted to the performance of its function?
4. To what segments are the appendages attached?
5. Describe the course of water through the branchial chamber.
6. Describe the walking, swimming, and other processes you have observed.
7. How are the maxillipeds and chelipeds used in feeding?
8. Be prepared to discuss the breeding habits, molting, economic importance, regeneration, and life processes of the crayfish.
9. Are all appendages biramous?
10. Are crayfishes edible?
11. What are well-digging crayfishes?

Exercise IX

SPIDERS AND OTHER ARACHNIDA

OBJECT: To become familiar with the general characters of spiders and to observe some of their adaptations.

DIRECTIONS: Select a wolf spider (Lycosidae) from your collection and note that the hairy body is composed of two main sections, the anterior or cephalothorax bearing the 8 legs,

the mouthparts, and the eyes; and the posterior portion (composed of 12 invisible segments) constituting the abdomen which bears the spinning apparatus.

On the anterior dorsal margin of the cephalothorax are located the simple eyes or ocelli, usually eight in number. Note the arrangement of the eyes. Due to the curvature of the cephalothorax some of the eyes are directed upwards, others look downwards, while still others look sidewise. Draw.

Below the eyes are the mandibles (chelae, chelicerae, or folces) which are the weapons of defense and offense. They are not true jaws. The mandibles consist of two parts, a basal segment (falx) and the grooved, pointed fang which is hollow and with which poison is hypodermically injected into the spider's victims.

Below the mandibles are the mouthparts, of which the palpi are the most conspicuous. The palpi differ in males and females. In the latter the palpus ends like a foot and is usually equipped with claws. It is used to dig, hold food, and handle the cocoon. On the male the palpi are frequently very highly colored and conspicuous. The male palpus usually ends in a bulb, the digital joint being a genital organ which transfers the seminal fluid to the female.

On the under side of the abdomen near the anterior margin the female epigynum enclosing the reproductive orifice is visible. The male opening is difficult to see.

Note the relative lengths of the legs and observe that there are seven segments which from the proximal end are: coxa, trochanter, femur, patella, tibia, metatarsus, and tarsus. Compare with an insect's leg. Compare the legs of running, jumping, and sedentary spiders.

At the posterior end of the abdomen note the spinnerets. These are so variable in different groups that detailed studies should be made with the suggested references.

Draw a spider from above and below, showing attachment of legs, spinnerets, etc.

Compare a mite, tick, and harvestman with a spider. How many body regions are there? Is the head region distinct? How does Limulus exhibit the characters of the group?

REPORT

1. Investigate the habits of the various web builders.
2. Is there any justification for the "little Miss Muffet" attitude toward spiders?
3. What are some courtship behaviorisms of spiders?
4. What are "ballooning spiders"?
5. What is the epigynum?
6. Is the epigynum of any taxonomic value?
7. What is the cribellum?
8. To what are the chelicerae homologous?
9. Do all arachnids have two body regions?
10. Are all spiders oviparous? Do all of them carry cocoons?
11. List the types of webs made by spiders.
12. What native spiders are poisonous?
13. How are spiders beneficial?
14. What is the significance of the musical composition "Tarantelle"?
15. To what family does the black widow spider belong?

Exercise X

MYRIAPODS

OBJECTS: To identify and distinguish between centipedes and millipedes.

DIRECTIONS: Several representatives of the centipedes (Chilopoda) and the millipedes (Diplopoda) should be examined and compared.

I. Examine a centipede and note the length and shape of the antennae. Examine the eyes with a hand lens. How many components? Are they aggregate? Do eyes vary in the specimens at hand? Examine the jaws. Are mandibles and maxillae present? Count the segments. How many are there? How many segments bear appendages? Which ones bear legs? Where are they attached to the segments? How many segments is each leg composed of? How many legs are borne on each segment? On the segment back of the head note the poison "jaws." Are these modified legs? At the end of the body are located the external reproductive structures. Are they homologous with the legs?

II. Examine several millipedes of different families. How do they compare in shape with the centipedes? How do the flattened Polydesmids differ from centipedes? Are the antennae the same shape and length as those of centipedes? Look for eyes. If present, what kind are they? How many body segments are there? Is each segment really a fusion of two segments? How many leg-bearing segments are there? How many legs on each segment? Are the first and last pairs of legs alike? Look for the reproductive processes on the seventh segment (males). These are legs modified for copulatory purposes. Scent glands are present on many species. These open laterally in the body segments.

III. Tabulate the characters of both centipedes and millipedes in comparative lists.

REPORT

1. Show by outline sketches the fundamental differences between millipedes and centipedes.
2. What constitutes the food of centipedes? Of millipedes?
3. What are the defenses of both groups?
4. What are the enemies of both?
5. Do these animals have a thorax?

6. Are native centipedes dangerous?
7. Do centipedes and millipedes have any economic importance?
8. What do the names centipede and millipede mean?
9. Do both millipedes and centipedes lay eggs? Where?
10. Do they undergo a metamorphosis?
11. Are they ever found in houses?
12. Do they hibernate? Where?
13. What are their reactions to light?
14. How do they breathe?

Exercise XI

INSECT ANATOMY

OBJECT: To become familiar with the structural make-up of insects.

DIRECTIONS: Using a grasshopper as an example of a generalized insect, note that the body is divided into three distinct sections, namely, the head, a middle region called the thorax, and the segmented abdomen. Note the large-sized, triangular head. The head bears: (1) a pair of long, thread-like antennae (examine them with a lens and describe their structure. Where are they attached?); (2) one pair of compound eyes (note their position. Are they situated so as to have a wide range of vision? Examine the compound eyes with a hand lens and observe that each eye is composed of numerous facets. These are the ends of individual components called omatidia which constitute the compound eye); (3) the ocelli or simple eyes (how many are there? How are they arranged? Under a lens how do they differ from the compound eye?). Make a drawing of the head from the front, showing all visible structures.

Examine carefully the mouth and its appendages. It consists of first an upper lip or labrum which is movable. Remove the labrum

and the chitinous jaws or mandibles will be exposed. Carefully remove the mandibles and another pair of jaws called the maxillae can be seen. Attached to each maxilla is a long, slender, five-segmented, leg-like structure, the maxillary palpus. Using the illustrations of mouthparts in your text, locate the parts of the maxilla—palpus, galea, lacinia, stipes or footstalk, and the cardo or hinge. The lower lip or labium is similar in a way to the maxilla and is composed of the mentum, submentum, palpiger, glossa, paraglossa, and the labial palpus. The tongue or hypopharynx is a fleshy organ more or less united with the base of the labium. Are the mouthparts adapted to chewing or sucking? Arrange the mouthparts in the order in which they are removed and make a drawing of all parts. Label each part carefully. Make an enlarged drawing of the maxilla and the labium showing the component parts of each.

The thorax or middle region is typically composed of three segments: an anterior segment, the prothorax; a middle segment, the mesothorax; and a posterior segment, the metathorax. In the more specialized flying insects these segments are not visibly distinct. Note that there are three pairs of legs, one pair attached to each thoracic segment. There are two pairs of wings, one pair attached to the mesothorax and one pair on the metathorax. The dorsal surface of the thorax is called the tergum. The sides are the pleura and the ventral side is the sternum. Note that the thoracic segments are composed of chitinized areas called sclerites.

Are the three pairs of legs alike? What are the functions of the three pairs? Examine a leg carefully, noting its attachment to the thorax. The leg is composed of five segments. The segment attaching the leg to the body is the coxa, next to which is a triangular segment called the trochanter. The enlarged portion of the leg is the femur or thigh. The slender tibia is attached to the femur and the distal segment, the foot or tarsus is composed of several segments including a claw. Are spines present on any of the leg segments? Draw a hind leg labelling all structures.

Note the differences between the front and hind wings. The inflexible, opaque front wings or tegmina are protective coverings for the fan-like, often brilliantly colored hind wings. What are the functions of the wings?

The abdomen is the posterior body region. How many visible segments are there? Are there any appendages on the abdominal segments? Along the sides of the first abdominal segment note the almost circular, membranous structure called the tympanum. This is the ear drum. Along the sides of the abdomen note the small pore-like openings, one pair to each segment. These are the spiracles or breathing pores through which air is drawn into the tracheal system.

On the tip of the abdomen are the genitalia or external reproductive structures. Compare several specimens and note the difference. In the male the genitalia consist of claspers, while the female possesses ovipositors through which the eggs are deposited in the ground. Can you select males and females?

Make a drawing of the entire specimen from above showing the wings extended on one side and the legs on the other.

Note the skeleton again. Is it flexible? The segments are movable. How is this affected? Does the head move up and down or sidewise? How is this movement related to the positions of the jaws?

It is suggested that the dissected parts be glued in order on a card and properly labelled.

Compare a roach, cricket, honey-bee, and ground beetle with the grasshopper.

REPORT

1. What are the stages in the development of a grasshopper?
2. In addition to jumping, what other functions have the hind legs?
3. How does a grasshopper see?

4. In what way are the eyes strategically located?
5. What are long-horned and short-horned locusts?
6. How does a cricket hear?
7. How do katydids, grasshoppers, and crickets sing?
8. Where is the tympanum on a katydid? A cricket?
9. How are the bodies of roaches, grasshoppers, and crickets different? Where do these insects live? Is the body shape adapted to habitat in each case?
10. What are young grasshoppers called?
11. Where do crickets, grasshoppers, katydids, cockroaches, and walkingsticks deposit their eggs?
12. What is a mole cricket?
13. Compare the Crustacea, Arachnida, Myriapoda, and Insecta with respect to: body segments and regions, legs, antennae, and eyes.

Exercise XII

STRUCTURAL MODIFICATIONS OF HONEY-BEE LEGS

OBJECT: To observe the specialized adaptations of the legs of honey-bee workers.

DIRECTIONS: The honey-bee is a highly specialized insect in which there are to be observed some interesting structural adaptations to the general habits of the insect.

Mount the three legs of one side of a worker bee in a normal order.

Using a magnifier, draw the outside aspects of the front and middle legs and both the outer and inner aspects of the hind leg. Be sure to see and label all of the essential structures. Note the branched pollen hairs on the bases of all legs. On the fore leg locate: the semi-circular scraper on the basal segment of the

tarsus; the velum, an appendage at the distal end of the tibia (this completes a circular comb when the leg is bent); the brush of hairs on the front margin of the tibia (to clean the comb); the erect spines along the anterior margin of the first tarsal segment (eye brush).

On the middle leg note the spur at the apex of the middle tibia for cleaning wings and removing pollen from the pollen basket.

On the hind leg note the corbiculum or pollen basket on the outer surface of the tibia; the wax pincers at the junction of the tibia and the tarsus; the pollen combs on the inner surface of the basal segment of the hind tarsus (for removing pollen from opposite leg); the auricle on the basal segment of the tarsus (pushes the gathered pollen into the pollen baskets).

REPORT

1. Describe the uses of the various structures observed, in the gathering and manipulation of pollen.
2. Tell how the wings, antennae, and eyes are cleaned.
3. Are all of these structures present on drones and queens?
4. Where does the pollen first accumulate?
5. How is the pollen from the corbiculum deposited in the cells of the hive?
6. What structures manufacture the wax?
7. What is done with the pollen after it is gathered?
8. How is honey made?
9. Describe the organization and division of labor in a beehive.
10. How many times can a honey-bee sting? A bumble bee?
11. Is nectar gathered by the legs?
12. What causes bees to swarm?
13. Do male bees sting?
14. How is the wax handled?
15. How does a beehive illustrate a society?

Exercise XIII

ADAPTIVE RADIATION IN THE LEGS OF INSECTS

OBJECT: To observe some further structural modifications of insects' legs and to determine their adaptations to special habits.

DIRECTIONS: Insects inhabit all kinds of situations. Most of them are structurally adapted to the media on or in which they live. Digging forms would necessarily have different kinds of legs from swimming insects. By examining the legs of running, jumping, grasping, swimming, and digging insects, the principle of structural adaptation will be demonstrated.

Examine and draw the legs of the following insects. Describe their adapations to the suggested habits.

1. Grasshopper–hind legs (jumping), first 2 pairs (clinging)
2. Tiger beetle–all legs (running)
3. Mole cricket–fore legs (digging)
4. Scarab beetle (male)–fore legs (digging)
5. Dytiscid beetle (male)–fore legs (suctorial pads for clasping)
6. Dytiscid beetle–hind legs (swimming under water)
7. Giant water bug–fore legs (seizing)
8. Giant water bug–hind legs (swimming)
9. Preying mantis–fore legs (grasping)
10. Water boatman–hind legs (swimming)
11. Backswimmer–hind legs (swimming)
12. Whirligig beetle–hind legs (swimming)
13. House fly–tarsi of all legs (adhesive pads)
14. Dragonfly–basket legs
15. Cockroach–all legs (running)
16. Metallic long-legged fly, male (Dolichopodidae)–fore legs (sexual adornment)
17. Pomace fly, male (Drosophilidae)–fore legs (sexual adornment)

REPORT

1. Recall the adaptations of the feet and legs of mammals and birds.
2. How general is the principle of morphological adjustment?
3. Suggest the ways in which the various legs of the above insects function.
4. What homology exists between an insect's leg and the legs of a crayfish?
5. Does the adaptive radiation of insect legs prove that environment induces structural conformity?
6. Are acquired characters inherited?

Exercise XIV

THE MOUTHPARTS OF THE HONEY-BEE

OBJECT: To develop a knowledge of insect mouthparts and their adaptive features.

DIRECTIONS: Carefully remove the mouthparts of a honey-bee worker and spread them on a microscope slide. Cover them with Canada balsam and a cover glass. Using a magnifier, determine the following parts: (1) well-developed mandibles or short chitinized jaws for cutting; (2) the simple labrum or upper lip; (3) the tongue or glossa, a long, flexible organ terminating in a spoon or labellum (the glossa is covered with several kinds of hairs which serve to gather nectar and for sensory and mechanical purposes); (4) the maxillae and labial palpi which form a tube which embraces the tongue; (5) the epipharynx which is situated between the bases of the maxillae and completes the tube (it is through this canal that nectar is drawn); (6) the mentum which is prominent and upon which the tube with all its parts

is seated; (7) the paraglossa which are on either side of the base of the tongue; (8) the submentum which is the segment back of the mentum which is attached to it in a typical manner; (9) the maxillary palpi which are very short structures seen at the bases of the maxillae.

After drawing the mouthparts, compare them with the mouthparts of the grasshopper in which a less specialized condition is seen. Compare with the sucking tube of a butterfly and a bug. The student is referred to a textbook of Entomology for more minute details.

REPORT

1. Does a honey-bee gather both nectar and pollen with its mouth?
2. What becomes of the nectar gathered?
3. Write a paper on the manufacture of honey.
4. How does the mouth of the honey-bee worker compare with the mouths of other sucking insects?
5. Is the mouth a factor in the cross-pollination of flowers?
6. Does a drone have a mouth similar to that of the worker?
7. Why do some adult moths have no functional mouths?
8. Do adult male dobson flies have mouths adapted to feeding?

Exercise XV

COMPARATIVE INSECT STUDIES

OBJECT: To become familiar with the characters of the various insect orders.

DIRECTIONS:

I. Compare a dragonfly and a damselfly in size and sturdiness. Note the shapes and relative sizes of the front and hind wings

on both insects. How do they differ? Compare the eyes of the dragonfly with those of the damselfly noting size, shape, and distance apart. In life the eyes of the dragonfly are glassy or transparent while those of the damselfly are opaque. Can you distinguish between males and females? The genitalia will indicate the sexes. Note the basket legs in which food is carried and the jaws with which food is captured. What is their food and how is it taken? Do these insects have antennae?

II. Examine a cicada and a giant water bug or stink bug. Note the needle-like mouth on the cicada and the awl-like mouth of the water bug. All bugs have a piercing and sucking, tubular mouth.

The wings on the cicada are clear and transparent and all four wings are similar (Homoptera). On the bug the wings overlap at their tips and they are opaque excepting at the distal portions, giving them the appearance of being half-wings (Hemiptera). Note the seizing front legs of the water bug. Compare these insects with the water scorpion, bedbug, aphid, and several other sucking insects.

III. Compare a butterfly and a moth with respect to size and hairiness of body, antennae, and position of wings at rest. Note the coiled sucking tube which serves as a mouth on the butterfly. Examine the wing of each under a microscope and note the wing scales (Lepidoptera).

IV. Compare a housefly and mosquito or cranefly (Diptera) with a honey-bee and a yellow-jacket or other wasp (Hymenoptera). Note the four wings on the bee or wasp. What is their nature? How do they compare in size? Where are they attached? Note the size and shape of the antennae. Examine the posterior margin of the hind wing under the microscope and note the row of hooks or hamuli with which the wings are held together in flight. How do these insects compare with ants which are members of the same order?

Examine a housefly. How many wings has it? Note the bal-

ancers or halteres just back of the wings. These are prominent on mosquitoes and craneflies. Examine the foot of the housefly and determine the parts. Look for antennae on the fly. Compare with the bee in this respect.

V. Compare a grasshopper and a roach with respect to number of wings, shape of body, size of head and eyes, length of legs, and antennae. These insects belong to the same order (Orthoptera). How are they similar? In what ways are they different? Do both have the thickened, inflexible front wings (tegmina)? Compare them with the walking stick, cricket, and katydid. Does the cricket have four wings? Examine the wing cover of the cricket and note the stridulating structures. On the side of the abdomen beneath the wings of the grasshopper note the tympanum or ear drum. On the cricket and katydid see the small, light-colored, depressed tympanum on the inner side of the tibia of the front leg.

VI. Select several beetles (Coleoptera) and note the variation in shape and color, the hard, horny outer wings (elytra) which meet in a straight line along the dorsal side. This is a positive character of identification in all beetles whether hard or soft and regardless of shape. Lift the outer or anterior wings (elytra) and carefully spread out the membraneous hind wings. Note the fold on the costal and anterior margin of the hind (flying) wings. This makes it possible for the elytra to completely cover and protect the hind wings when at rest.

REPORT

1. Make a list of the insect orders and indicate the number of pairs of wings, adaptation of mouthparts, and metamorphosis of each order.
2. Does the absence of long antennae on dragonflies and flies suggest rapid flight?
3. How do grasshoppers and katydids sing?

4. Where do grasshoppers, crickets, roaches, and katydids lay their eggs?
5. How and where do dragonflies and damselflies lay their eggs? What are their young like?
6. What are the characters of fleas, lice, aphids, mayflies, stoneflies, and earwigs?

Exercise XVI

ANT STUDIES (1)

OBJECT: To become familiar with some activities of ants.
DIRECTIONS:

I. The student should review the lectures on ants and also be familiar with additional information contained in W. M. Wheeler's *Ants*. It would require many months to observe all of the activities of ants but even a few original observations will captivate the interest of the watcher.

Visit some ant hills and spend several hours observing their normal activities. Look for contacts, feeding, communications, etc. Drop some grains of sand into the burrow and observe the resultant actions.

Place a dead insect or a particle of food near the burrow and observe the responses. When the ants begin to drag the creature toward their burrow, place a few small sticks or stones in their path.

At another hill tap gently on the ground near the burrow.

Place some fruit (banana or apple) on the ground near the entrance. Test their reactions to chemicals by sprinkling perfume and CS_2 on the ground near the entrance to the nest.

Dig into the burrow with a trowel and gather as many different kinds of individuals as you can. Also take some larvae and pupae. Look carefully for "guests."

Observe the activities of the colony when their young are exposed.

II. Stock an artificial nest for observation in the laboratory and observe their habits. The Austen Ant Nest or other types available at supply houses serve admirably for laboratory purposes. The ant nest can be removed from the ground with a trowel and placed in a wide-mouthed jar for transportation to the laboratory. Loose surface material should be scraped from the ground around the nest. In stocking, the nest can be placed on bricks placed in a sink or dishpan and surrounded by water to prevent the escape of the ants.

REPORT

1. What is the nature of the ant nest observed?
2. How are their burrows made?
3. Do ants manifest unrest at your presence and at your tapping on the ground? How?
4. Do they attempt to remove the obstacles placed in their paths?
5. What kinds of guests are found in ant nests?
6. What are the duties and interrelationships of the various castes?
7. When do ants have wings?
8. Is number of individuals an indication of a species' success?

Exercise XVII

ANT STUDIES (2)

OBJECT: To observe the relationships between ants and plant lice.

DIRECTIONS: In the summer one can always find myriads of plant lice on cocklebur, golden glow, and many other plants.

Locate a plant that is infested with plant lice and observe the animals associated with them. The principal forms will be ants and ladybird beetles with their larvae.

Look carefully to see if ants carry plant lice and observe any contacts between the two animals. A magnifying glass will assist in observing what takes place between the two kinds of individuals.

Record everything you see that the lice, the ladybird beetles and their larvae, and the ants do. You should capture a beetle and, holding it between the fingers, place a plant louse in its mouth with fine forceps.

It may require several hours of close observations to determine the relationships between these insects but it is time well spent.

REPORT

1. Do ants transport plant lice?
2. Do they stroke them with their feet or antennae?
3. Do the ants eat the discharge from the intestines or from other body structures?
4. Do both the larval and adult "ladybugs" eat plant lice?
5. Do the plant lice seem disturbed at the coming of either ants or beetles?
6. Is the relationship between ants and aphids symbiotic or a mild form of parasitism?
7. Does social organization tend to extend the principle of deriving benefit from others to different species?
8. What human activities are duplicates of ant behavior?

Exercise XVIII

INSECT RESPIRATION

OBJECT: To observe some of the various breathing mechanisms of insects.

DIRECTIONS:

I. Examine the sides of the abdomen of a grasshopper and note the spiracular openings. Look for the spiracles on the dytiscid and hydrophilid beetles and on the giant water bug Benacus. Note their positions. How do they compare with the grasshopper?

II. Examine the caudal, leaf-like gills on the posterior end of the abdomen of a damselfly nymph under a compound microscope. Note the tracheoles. Draw a portion of the abdomen showing the three gills and make a drawing of one of the gills as seen under the microscope. The gills of a dragon fly nymph are within the cloacal aperture.

III. Examine the abdomen of a mayfly nymph and note the tracheal gills along the sides (7 pairs). Make a drawing of the abdomen showing the location and structure of the gills.

IV. Examine the thorax of a stonefly nymph from beneath and note the tufts of thread-like gills at the bases of the legs. Draw the under side of the thorax showing the gills in position.

V. Draw the ventral side of a hellgrammite or dobson fly larva, showing the tufts of white, hair-like gills on the first seven abdominal segments.

VI. Make a drawing of the ventral side of a water penny showing the five pairs of whitish gills in position.

VII. Note the tracheal tubes at the posterior end of the body of a mosquito larva and make a drawing showing their position. Locate the tracheal tubes on the thorax of a mosquito pupa.

VIII. Examine a black fly larva with a compound magnifier and show in your drawing the three retractile blood gills on the posterior end of the body.

IX. Note the two posterior spiracles on the larvae of a dytiscid beetle. Make a drawing of a section of the abdomen showing the spiracles.

X. Make a drawing of the abdomen of a water scorpion showing the two breathing tubes at the posterior end of the body.

REPORT

1. How do some adult insects such as water boatmen, waterbugs, and diving beetles breathe under water?
2. Distinguish between open (holopneustic) and closed (apneustic) breathing systems.
3. What are the relative positions of the spiracles on adult water insects in comparison with terrestrial forms?
4. How is oxygen received by the caudal gills on a damselfly nymph?
5. What insect breathes through its antennae?
6. How do fly larvae breathe?
7. How do diving spiders breathe under water?
8. How do adult water insects get air?

Exercise XIX

STUDY OF A FISH

OBJECT: To become familiar with the external features of a fish and to test the mechanical efficiency of its shape and structures.

DIRECTIONS:

I. Examine a perch or other fish and note the eyes, nostrils, upper and lower jaws, opercle or gill cover, anus, and fins. How many fins are there? Where are they located? Are there one or

two dorsal fins? Which is larger? Which has the coarser and more sturdy fin-rays? Are these rays erectile? Is the caudal or tail fin forked? Rounded? Note the exact positions of the ventral, anal, and pectoral fins. Compare the fins of several species of fishes. How do they differ? Compare the local species with a flying fish and a sail fish (pictures will do).

Note the mouth—its size and position. How does it compare with the sucker and catfish?

Observe the arrangement of the scales. Do all fishes have visible scales? (See trout and catfish.) Is there a definite lateral line of scales on each side? Pull out several scales. Are they toothed on their posterior margins? These teeth are ctenii and are attachments. Not all fishes have ctenoid scales.

Place a scale under the microscope and observe the rings of growth. These indicate age.

Lift the opercle and note the pinkish gills and the gill rakers. The latter are to strain particles from the water which passes over the gills. Does water pass into the mouth or through the opercula?

II. Observe a live fish swimming. Its streamline body moves gracefully through the water. What is the propelling force? Do the ventral and pectoral fins function in propulsion? Are these fins held against the body as the fish swims? When the fish stops or turns, which fins are used? Is the dorsal fin raised while swimming? Is it raised when the fish is still? Are the rays of any other use than to give rigidity to the dorsal fins? When a live fish is handled, do the dorsal fins become erect? Is the spinous character of protective value?

Observe the eyes. Are they colored? Are eyelids present? Are they movable? How frequently does the fish open its mouth to breathe? Would this depend upon temperature and oxygen supply?

Compare the fins with those of the darter, stickleback, and the blob. In these are any of the fins used for anchorage on the bottom?

III. To test the function and efficiency of the fins, perform the following class experiment using goldfish or minnows. Remove the dorsal fin. Does the fish have any difficulty in remaining upright? Is there an excessive use of the pectoral or ventral fins? Remove the pectorals. What happens? Then in turn remove the ventrals and the anal fins respectively. Test each set individually, observing what happens and noting excessive use of other fins. Your experiments will reveal that the back is heavier than the underside and that the front end of the fish is heavier than the posterior end. They will also show that the vertical surface offered by the dorsal fin or fins helps to keep the fish in a normal position.

The streamline form plus the slimy covering are adaptations, offering little friction between the fish and the water through which it swims. Bottom forms, free-swimming kinds which cruise about in open water, and the species which lurk among aquatic plants have differently shaped bodies. The latter are laterally flattened and they usually have more or less conspicuous crossbars of darker color. Why?

REPORT

1. Name some cold-water fishes of fresh water.
2. What common species can be kept in aquarium tanks? What ones cannot live in laboratory aquaria?
3. Where is the swim bladder? What are its functions? Do all fishes have a swim bladder?
4. How do fishes hear? Can they smell?
5. Do fishes ever bring forth living young?
6. How are the eggs fertilized by the male?
7. What common fishes build nests?
8. What are "game fishes"?
9. Do fishes have protective coloring?

10. What are enemies of fish? (Mammals, birds, snakes, turtles, salamanders, insects, other fishes, mussels, crustaceans, fungus diseases.)
11. How are fishes protected by laws?
12. How are commercial fishes artificially propagated?
13. Are all fishes good to eat?
14. How do catfishes "sting"?
15. List the fishes found in rapid streams.
16. Describe the life history of the eel.
17. Why does a fish die out of water?
18. How can freshness of fishes offered for sale be determined?
19. What are ganoid and cycloid scales? How do they differ from ctenoid scales?

Note: The dissection of a fish would be a valuable exercise. Directions can be found in many zoölogy manuals.

Exercise XX

A STUDY OF THE FROG

OBJECT: To become familiar with the external features, development, habits, and adaptive features of the frog and to compare the frog with other amphibians.

DIRECTIONS: Most frogs are aquatic and are therefore found in or near fresh water. Some kinds, however, such as the wood frog and the tree frog, may be found in damp woods either on the ground or on the trunks and branches of trees. The toad, which is closely related to frogs, is terrestrial and may be found at considerable distances from the water. It migrates back to water for breeding purposes and its eggs are always deposited in shallow water in ponds or streams. Frogs lay their eggs in irregular clusters, while toads lay their eggs in strings which are enveloped

with a gelatinous mass and draped over plants and other objects in the water.

Study a live frog and note the position of the elongated hind legs when at rest. They are always flexed, ready to jump. When at rest at the surface of water, however, the hind legs are extended, ready for a forward push so that it may swim to the bottom. The front legs guide the jump and they serve to direct the swim. The webbed hind feet are splendidly adapted to swimming. The forward nares or nostrils and the bulging eyes are located so that, when resting at the surface, they alone protrude. The frontal organ or brow spot is a pigmented area between the eyes. Note that the body is composed of a head and trunk. No neck is present.

The skin rather loosely covers the body and is smooth and slimy. When attacked the frog can swell up considerably. This makes it difficult for the attacker to hold or swallow the frog.

External Features. Note (1) the paired nostrils or external nares; (2) the eyes with a slightly movable upper eye lid and a lower movable lid which is transparent (nictitating membrane); note the bulge of the eyes; (3) the circular tympanic membranes or eardrums just back of the eyes; (4) the two unequally developed pairs of legs (the fore limb consists of the upper arm, fore arm, wrist, and hand which bears four digits, the thumb being reduced to only a rudiment which can be felt through the skin. The hind leg is composed of the thigh, shank, and foot with a long ankle region and bearing five digits. The shortest digit, the hallux, is homologous with the big toe of humans); (5) the opening of the cloaca or anus on the dorsal surface between the hind legs.

Open the mouth and note the heavy, muscular tongue attached by its anterior end to the floor of the mouth. This makes it possible to extend the tongue for a considerable distance. It is sticky, is forcibly ejected by a swelling of a lymph space beneath the tongue, and strikes insects which stick to it. Posterior to the tongue, on the ventral side of the mouth, is the raised, circular

glottis which has a median slit through which air is transmitted to the trachea into the larynx or voice cavity and then into the lungs. On the back of the upper jaw on either side is the opening of the Eustachian tube which leads to the cavity of the middle ear. A needle thrust carefully through these openings reveals their courses. Anterior to the openings of the Eustachian tubes are the internal nares or olfactory openings which lead to the nostrils. A probing needle carefully inserted through the nostril reveals their position. The internal nares lie on either side of dorsal sets of vomerine teeth. Numerous other small, bony teeth are borne around the margin of the upper jaw. They are not masticatory in function but serve to hold and crush food. The bony portion of the upper jaw is enclosed by a fleshy upper lip. This is not present in the lower jaw. The lower jaw fits into the groove (Sulcus marginalis) of the upper jaw when the mouth is closed.

The mouth or buccal cavity connects with the gullet or anterior end of the oesophagus.

If a live frog is studied, wrap one of the hind legs with a piece of cloth and spread the web of the hind foot under the low power of the microscope and observe the circulation of the blood. Keep the web moist.

Frog Eggs. Secure in the spring, if possible, some fresh frog eggs. Examine them with a hand lens and note the jelly encasement. What is its function? Also observe that the egg is composed of a light, cream-colored portion (the vegetative pole containing nutrient matter) and a black portion (the animal pole in which the frog develops). This side is usually uppermost in the water.

Keep some frog eggs in a fresh-water aquarium and observe their development by examining them each day. The cleavage of the eggs can be studied through the blastula and gastrula stages and the formation and development of the embryo can be observed.

The newly hatched tadpole will have a sucker-like mouth and

external gills. It will remain attached to an object for several days and the gills will disappear. Stones covered with algae will provide ample food at first. Later, pulverized granular fish food can be used, and when the legs begin to develop, earthworms or ground meat should be supplied.

Salamander eggs can also be collected in the spring and their development can be observed. On the salamanders the front legs will appear first.

A toad, newt, and mud puppy should also be studied and compared with the frog. Preserved specimens of these should be available in the laboratory for comparative studies.

REPORT

1. In breeding, the male frog clasps the female while she deposits the eggs. Is the fertilization internal or external?
2. Describe the development of the frog egg.
3. How can sexes be distinguished?
4. How do males and females find each other?
5. Do female frogs croak?
6. How is croaking effected?
7. How does the throat become distended during croaking?
8. Are frogs protectively colored?
9. What is the so-called summer sleep of frogs?
10. What modifications of structure enable tree frogs to climb?
11. What are the principal enemies of frogs and toads?
12. What means of defense has a toad?
13. What are the chief characters or the Amphibia which distinguish them from reptiles and other animals?
14. List the native species of frogs and toads.
15. Are there any secondary sexual characters evident in frogs during the mating season?
16. What becomes of the tail of a tadpole as it develops?
17. Where are the front feet of a frog while the hind legs only are visible?

18. List the native newts and salamanders.
19. Are any newts and salamanders terrestrial?
20. Does the development of the frog suggest one of the courses of evolution?
21. Do frogs possess the ability to change colors?
22. What is the chief adaptive feature of the protruding eyes?
23. What becomes of the external gills of the newly born tadpole?
24. Is the skin adapted to respiration?
25. What are tree frogs? woods frogs?
26. What are the differences between a frog and a toad?

Exercise XXI

SOME FEATURES OF SNAKES

OBJECT: To observe some common and little known features of snakes.

DIRECTIONS: The snakes are an important part of the fauna of a region. Because so many foolish superstitions have been built up around them, the average person is ignorant of their real nature. On the whole, snakes are just as interesting and as highly specialized as their relatives, the turtles and lizards.

Secure a common *harmless* snake such as a garter, water, black, or house snake of small size and make the following observations. Note the size and shape of the body. Is it long and slender or short and thick?

Note the shape of its head. Is the neck prominent or are the head and neck about the same size?

Place the animal on the ground and observe its locomotion, noting particularly its undulations. Then place the animal on a smooth table or plate of glass and observe the speed at which it travels and the body undulations.

Note the activity of the tongue. How frequently is it extended? Is it forked?

Put the animal on a shrub and note its movements in climbing and descending.

Kill the animal (or better still, use a specimen already preserved and release the one you have) and measure its total length. Then measure the tail (distance from anus to tip of tail). If possible, use a *preserved* specimen of a copperhead or rattlesnake and compare it with your specimen.

You will note that the animal is covered with scales. Compare the snake with a turtle (scales fused together) and with a salamander. Note differences and similarities.

On the ventral surface the scales are transverse plates or scutes. With a needle or knife blade determine which edge (anterior or posterior) is comparatively free.

Note particularly whether the anal scales (those on ventral side back of the anus) are like the abdominal scales. Compare the nonpoisonous and poisonous snakes in this regard.

Examine the eyes. Is there a movable lid? Is there a pit above the nostrils?

With forceps open the mouths of both the snakes, note the number and curvature of the teeth. Where are the fangs located? Is the lower jaw flexible?

Feel along the body and note the numerous ribs and the lack of rigidity of the skin and muscles.

REPORT

1. List all of the obvious differences between poisonous and nonpoisonous snakes.
2. Which has the more graceful body? Which body shape suggests the greater speed?
3. How do snakes run? Why the difference in effort when the snake was placed on a smooth surface?
4. What are the differences between a reptile and an amphibian?

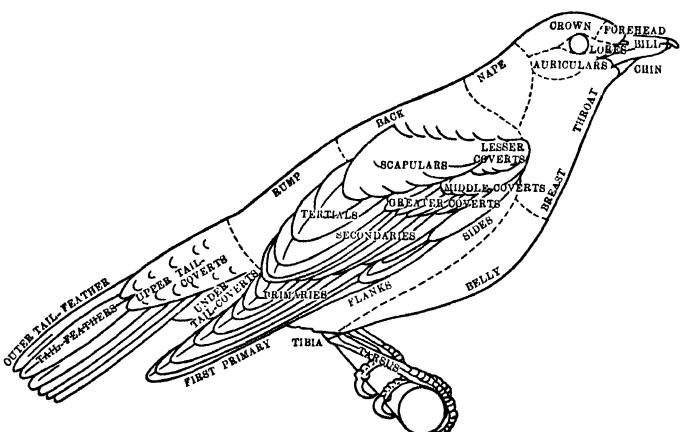
5. Why are the teeth recurved?
6. What common snakes lay eggs?
7. Is the forked tongue a sign of virulence?
8. List all of the superstitions you have heard about snakes.
9. How can snakes swallow animals larger than themselves?
10. Are snakes "slimy"?

Exercise XXII

BIRD DESCRIPTIONS

OBJECT: To learn to properly describe a bird in the field.

DIRECTIONS: As a rule, a bird is identified by two or three characters at most. The experienced ornithologist will identify various birds by flight mannerisms, signal markings, body shape,



call, etc. The beginner must resort to general descriptions until a familiarity with each bird is established.

Using the topographical chart in your text and a collection of bird skins and bird pictures, describe ten birds in terms of their entire topography. This will develop an ability to write field descriptions in proper terms.

In all cases the size of the bird should be determined and recorded with the description. The length of tail, bill, and wings is also valuable.

Exercise XXIII

BIRD STRUCTURES AND THEIR SIGNIFICANCE

OBJECT: To become familiar with the adaptations of bird structures.

DIRECTIONS: A knowledge of the adaptive features of wings, feet, bills, and tails will make every bird interesting whether you know its identity or not. When you see a bird with long, well-developed feet and legs, you may rest assured that it spends considerable time on the ground. If it has grasping talons equipped with long sharp claws, it will probably have a hooked bill, which characters indicate that it is a bird of prey.

It is for the purpose of developing an ability to interpret a bird in terms of its environment that this exercise is designed. When you have finished your observations, you should be pretty well able to tell about where a bird lives, what it eats, and what its habits are, even though you may have never seen it before.

Examine the feet of the following birds and note the number, relative length, and arrangement of toes. Also note whether the legs are sturdy or weak.

Chicken–note the position of the legs on the body and the short raised hind toes (scratching)

Robin–all toes on the same level, hind toe long (perching)
Duck–webbed feet, legs back on body, bill spoon-like and margined with teeth (aquatic)
Great blue heron–long bare legs, lores bare (wading)
Meadowlark–legs stout, four toes (perching)
Chimney swift–feet and legs weak (aerial)
Hawk–strong grasping feet with claws (seizing)
Woodpecker–two toes in front, two behind (clinging to vertical surfaces)

Examine and draw the bills of the following birds:
Cardinal–large, seed cracking, bud eating
Sparrow–seed cracking
Hawk–decurved upper mandible–flesh tearing
Wren–long slender upper mandible hook–insectivorous
Swallow–short, shallow, wide–feeding on wing
Crossbill–scissor-like, crossed mandibles–for seed splitting
Snipe–long slender upper mandible flexible–for probing in mud

Examine the tails of the following birds:
Swallow–long, forked–graceful flight
Swift–short tail feathers with pin-like extensions–serve as prop
Woodpecker–tail feathers pointed and stiffened–serve as prop
Loon–tail almost wanting
Turkey gobbler–large fan-like tail–adornment for courting

Examine the wings of the following birds:
Hummingbird–long, slender, pointed–for rapid vibration
Hawk–broad–for soaring
Chicken–short for size of the body–seldom used
Penguin–paddle shaped–for swimming

REPORT

Write a summary of the adaptations of bird structures for all of the habits which characterize the various bird orders.

Exercise XXIV

BIRD STUDIES IN THE FIELD

OBJECT: To become familiar with some native birds, their haunts and habitats.

DIRECTIONS: Bird study is largely an individual matter. Large groups scare away the birds, while a single individual, inconspicuously dressed and proceeding very slowly, may get quite close to many birds.

The student will soon discover that birds too have their habitat preferences. Some inhabit the marshes or ponds, others will be found in open fields, some prefer the thickets along old fences, while still others are to be seen only in the woods.

Some (such as quail, meadowlarks, etc.) spend much of their time on the ground; others (woodpeckers, creepers, nuthatches) on the trunks of trees; some (warblers, chickadees, titmice) among the foliage of the smaller twigs; some inhabit the tree tops (orioles, etc.); others (hawks, vultures) soar high in the air.

By recognizing habitat preferences, altitude zonation, and secretive habits, bird study is made less difficult.

Always pause to look at a bird. Use field glasses when possible and hastily describe the birds you do not know in terms of the topographical chart. Record any mannerisms and activities which may assist in later identification.

Note: Flight mannerisms, feeding habits, secondary sexual characters, signal markings, all will be interesting and will aid in your again recognizing individual birds. For instance, the undulating flight of a flicker compared with the short, quick undulations of the sparrows; the searching under leaves by warblers compared with the sudden darts into the open by vireos and flycatchers after flying insects; the white band across the back of the redheaded woodpecker compared with the white rump of the flicker, the

white outer tail feathers of juncoes, meadowlarks, vesper sparrows, and chewinks; the crests of titmice and cardinals compared with the tail feathers of male ring-necked pheasants and the striking sexual color difference of buntings, goldfinches, and red-winged blackbirds are certainly characters worthy of note.

Keep your bird observations all year. In winter, the population is small, comprising creepers, nuthatches, chickadees, bluejays, cardinals, titmice, and others. At this time birds are more easily observed because masses of foliage do not obscure vision. When the spring migration starts, the beginner is confused by numbers but the riot of song and color of warblers, wrens, gnatcatchers, thrushes, etc., makes bird observations alluring.

In the summer, the courtship, nesting activities, and rearing of young reveal another interesting phase of bird life.

In the fall the southern migration gradually depletes the number of summer birds and many birds can be seen only during these periods of migration.

On every field trip carry your field glasses and record the date, locality, time, and activity of every bird you see.

Make a chart on which birds observed should be recorded. This chart should be in the form of a calendar and should be prepared for the entire period of the course.

Draw a habitat chart indicating the distribution of species according to altitude, woodland, open field, marsh, etc.

REPORT

Classify your final list of birds according to:

1. Winter residents
2. Birds of the open
3. Birds of the ground stratum
4. Tree protectors
5. Birds of the tree tops
6. Permanent residents

7. Visitors
8. Insectivorous
9. Seed eaters
10. Omnivorous
11. Predators
12. Carrion eaters
13. Birds of the marshes
14. Aquatic birds

Exercise XXV

INTRODUCTORY FIELD STUDIES

OBJECT: (1) To become acquainted with the general relationships of animals; (2) to get a conception of the diversity of animal life; and (3) to become generally familiar with some native animals and their places of abode.

DIRECTIONS:

I. The student should be equipped with a notebook and pencil, empty vials and vials partly filled with 80% alcohol, insect net, killing bottles, and an empty pint-size mason jar. General equipment for collecting water life will be supplied by the instructor.

In collecting animals in the field, look under stones, logs, and other objects on the ground. Many kinds will be found on the bark of trees and on the stems and leaves of other plants. There is quite a number of animal forms that live under water, and these can be taken with the dip nets supplied by the instructor. Whirligigs and water striders will be seen on the surface of the water.

Search every situation carefully and collect all small forms. Flying insects can be captured by using the net. Place all soft-bodied animals such as worms, spiders, ants, plant lice, and larvae in the vials of alcohol. Beetles, bugs, wasps, flies, dragonflies, and butterflies should be placed in the killing bottles.

Snakes should not be captured with the hands unless the instructor makes certain that they are not poisonous. Frogs, toads, and snakes are best carried in cloth bags which the instructor will supply. Water animals can be placed in alcohol or kept alive in the mason jar. All material should be kept for later study.

You should find beetles, bugs, plant lice, larvae, bees, flies, wasps, grasshoppers, crickets, and a host of other insects. In addition you should find spiders, slugs, snails, sowbugs, worms, and many other animals representing diverse phyla.

II. In your field notebook, record the exact situation in which each animal was found or observed. This means that the habitat (woods, sandy beach, under log in woods, on bark of tree, etc.) should be noted when the animal is collected.

Study the characters of animals as listed in the keys below and attempt to place all of the animals together; first, in their proper phyla; and second, in the classes. This will develop an ability to properly identify and establish the relationships of animals.

REPORTS TO BE SUBMITTED

1. Submit a list of animals observed, classified as far as phylum and class.
2. Indicate the various situations in which animals were collected (swamp, open field, etc.).

SIMPLE CLASSIFICATION SCHEME

Key to the Phyla

1. Single-celled animals in pond water: usually microscopic ..... *Protozoa*
   Multi-cellular animals, usually macroscopic 2
2. Sessile colonial animals found on rocks under water or in colonies submerged stems ..... *Bryozoa*
   Non-sessile animals, not colonial 3

3. Radially symmetrical–tubular body ..... *Coelenterata*
Bilaterally symmetrical 4
4. Unsegmented externally and internally 5
Segmented internally and usually with visible external segments 8
5. Mouth near middle of body on under side; body flattened dorsoventrally; primitive head process; eye spots usually visible ..... *Platyhelminthes*
6. With a large ventral muscular foot and usually with a bivalvular or univalvular shell ..... *Mollusca.*
Without a muscular foot or shell 7
7. With a ring of cilia around the mouth ..... *Trochelminthes*
Body without cilia; round and worm-like; head indistinct ..... *Nemathelminthes*
8. Body composed of numerous, ring-like segments; no external or internal skeleton 9
External segmentation not always visible; with internal skeleton and usually with two sets of paired appendages .... *Chordatat* (Vertebrata)
9. Without jointed locomotory appendages; worm-like 10
With jointed legs; body regions distinct ..... *Arthropoda*
10. With setae on ventral side or suckers at both ends of body ..... *Annelida*
Without setae ..... *Arthropoda* (larvae)

Key to the Classes of Protozoa

1. With pseudopodia ..... *Protozoa*
Without pseudopodia 2
2. With flagella (one or more) ..... *Mastigophora*
Without flagella 3
3. With cilia ..... *Infusoria*
Without locomotor organs and cilia in adult stage; parasitic ..... *Sporozoa*

Bryozoa

The Bryozoa or moss animals are difficult to classify into classes. They are jelly-like, almost clear animals commonly found on stones in running water or attached to submerged stems in fresh ponds. The common genera are: Paludicella, Plumatella, Cristatella, and Pectinitella. The last two Genera form larger colonies than the others.

Key to the Classes of Platyhelminthes

1. Free living; on stones in running water ..... *Turbellaria*
   Parasitic: usually in intestinal tracts of other animals 2
2. With an intestine ..... *Trematoda*
   Without an intestine; body segmented; head bearing hooks and suckers ..... *Cestoda*

Nemathelminthes

There are several classes of roundworms but they are difficult to identify. The body is elongated; unsegmented; head indistinct.

Trochelminthes

The rotifers are complex, extremely small animals characterized by a ring of rotating cilia on the upper surface. They are difficult to classify.

Key to the Classes of Mollusca

1. Shell composed of two equal halves or valves; bilaterally symmetrical ..... *Pelecypoda*
2. Shell composed of a single valve; usually spirally coiled .... *Gastropoda*
3. Elongated, snail-like animals with eyes and antennae but without a visible shell ..... *Gastropoda* (slugs)

Key to the Classes of Annelida

1. With setae; segments usually numbering more than 100 ..... *Chaetopoda* (earthworm)
2. Without setae and with suckers at both ends ..... *Hirudinea* (leech)

Key to the Classes of Arthropoda

1. Without thoracic or abdominal walking appendages ..... *Insecta* (larva)
   With thoracic or abdominal walking legs 2
2. Body with two regions, head and abdomen; no thorax visible; segments numerous; most segments bearing legs 3
   Head and thorax fused together; abdomen prominent 4
3. Middle segments with one pair of legs; antennae long ..... *Chilopoda*
   Body segments with two pairs of legs; antennae short ..... *Diplopoda*
4. With 2 pairs of antennae, one pair shorter; 5–8 pairs of biramous appendages ..... *Crustacea*
   Abdomen frequently larger than cephalothorax; no antennae; 4 pairs of thoracic appendages ..... *Arachnida* (spiders)

Key to the Classes of Chordata

1. Without jaws ..... *Cyclostomata*
   With jaws 2
2. With fins supported by rays; body usually with scales *Pisces*
   With or without fins, the latter never supported by rays 3
3. Without scales, feathers, or hair; body usually moist *Amphibia*
   With scaly skin ..... *Reptilia*
   With feathers ..... *Aves*
   With hair ..... *Mammalia*

Exercise XXVI

CLASSIFICATION OF ALL ANIMALS COLLECTED

OBJECT: This exercise is a term assignment and is placed here as such. The work will be done partly in the regular laboratory periods where, with the help of the instructor, skill in the classification of animals may be acquired.

DIRECTIONS: As has previously been indicated, all animals collected must be classified as to families. This requires a knowledge of phyla, classes, and orders of animals but goes much further into animal relationships. A knowledge of structures is essential.

A book to include keys to the families of all phyla represented in any region would be voluminous and no one person would be capable of the preparation of such a work without resorting to the writings of numerous investigators in all fields of animal taxonomy. The student is, therefore, referred to the bibliographies appended to each chapter in the text in which family determinations may be pursued. In any case, keys will be difficult and the student will be forced from time to time to turn to illustrations and to his instructor for assistance. In recognition of these difficulties which involve, at times, vague characters and diversity of structural terminology, each succeeding exercise will indicate the dominant animals in every situation. Consult the classification of habitats in your text.

The actual demands on the student will include only the family classification of the commonest and most dominant forms. The opportunity for each student to pursue studies in groups which command his special interest is in this way taken care of and students showing interest in special groups will be encouraged and assisted to go as far as they like.

The works suggested in the text are considered to be the most available, most general, and most authentic.

Exercise XXVII

WOODLAND ANIMALS

This exercise will require several trips.

OBJECT: To become familiar with the animals indigenous to shady woodland areas.

DIRECTIONS: While many animals are to be found only in these situations, there are many types of woods. They may be old or young, sparse or dense, damp or dry, etc. Then too, the vegetation itself will partly determine the life to be found in any woods. The forest may be evergreen or deciduous, and different trees such as oak, hickory, ash, or others may dominate in different areas. The procedure for study, however, is the same for all. Only the results will vary.

Woodland studies must be made slowly and patiently. Animals have numerous places to hide and they are less easily found in shaded places. At the first sign of danger activity ceases; animals warn each other of your presence. Birds stop singing and frequently sound alarms. Squirrels scamper out of sight. Insects remain quiet or seek places of safety. Thus it is necessary to approach and proceed quietly and slowly.

Examine the leaves and stems of the shrubs. Search carefully for forms on the ground and on the bark of trees. Capture flying insects. Record all bird, reptile, and mammalian observations.

Record carefully the exact situations in which animals are observed or taken. Note the height of nests, birds, mammals, and insects in the various forest strata. To fully understand the woodland animals this is necessary.

Careful studies will reveal chipmunks, squirrels, bats, snakes, land snails, box turtles, salamanders, lizards, frogs, and numerous birds, such as cedar waxwings, tanagers, grouse, towhees, flycatchers, vireos, woodpeckers, nuthatches, creepers, wrens, thrashers, warblers, bluejays, crows, and others too numerous to list here.

Many arthropods characteristic of the woodland such as spiders, craneflies, walking-sticks, tree crickets, smoky-winged damselflies, scorpion flies, bark moths, thysbe moths, tachinid flies, robber flies, hornets, etc., will be found by the careful searcher. Make your searches complete.

Open umbrellas and place them on the ground beneath a tree of moderate size. Shake the tree forcibly and gather fallen insects which tumble into the open umbrellas. The walking-stick is most easily gathered in this way, especially in late summer.

REPORT

1. List all animals observed and taken.
2. Arrange them according to strata, e.g., ground, low shrubs, tree tops, etc.
3. What animals in your list are truly woodland forms?
4. What arboreal animals did you see?
5. How did the various forms react to your presence?
6. Use references on birds and mammals and add additional forms to your list.
7. Make a diagram showing zonation of woodland animals.
8. What adaptive features have arboreal animals?
9. Are woodland animals adaptively colored?

Exercise XXVIII

ANIMALS OF THE OPEN FIELDS

OBJECT: To develop an acquaintance with the animals of open tracts.

DIRECTIONS: The investigator will soon learn that various animals have different habitat preferences. Some prefer open fields, while other forms frequent woodland areas. In every type of habitat there is, naturally, a seasonal succession of plants and animals.

Visit an open field or pasture, or better still, visit both. The neglected field will produce animals not found in pastures and vice versa.

Your visit will stimulate activity on the part of larger forms so it would be well to approach the place rather cautiously, keeping on the alert for them.

Vesper sparrows, cowbirds, meadowlarks, field sparrows, bobolinks, quail, goldfinches, and other birds will take wing. Rabbits, groundhogs, field mice, shrews, and various other mammals will dart to safety. Butterflies and grasshoppers will reveal themselves in flight. Beetles and bugs will drop to the ground or crawl to the undersides of leaves.

In fields where cattle, sheep, horses, or hogs are quartered, examine the manure for carrion insects such as silphid, histerid, scarabaeid, and staphylinid beetles, and numerous flies and their larvae. Careful observation will doubtless reveal "tumble bugs" (scarab beetles) at work.

Record all observations on birds and mammals and collect as many flying insects as possible. Search diligently on the leaves and stems of plants and look in flowers, seed pods, etc., for others. Look for the runways and burrows of meadow mice.

Many insects are more or less specifically associated with certain plants. Always note, when possible, the plants on which in-

sects are taken. Giant mullen, milkweed, evening primrose, goldenrod, violets, mint, and others have guests which are characteristic of these plants only.

After carefully searching the plants, go over the ground stratum slowly and carefully lift stones, boards and other objects. Crickets, spiders, grasshoppers, ground beetles, slugs, earthworms, tumble bugs, millipedes, and various other living things will reward your efforts.

When you feel that your search has been thorough, take your net and sweep the grasses and herbaceous plants carefully. Hundreds of smaller animals such as spiders, daddy-long-legs, leaf hoppers, stink bugs, flea beetles, small wasps, and others too numerous to list here will be taken. Place the contents of the net in an empty killing jar, then transfer the dead mass to properly labelled vials or pill boxes.

On mud flats and in corn fields you may see holes with mud chimneys around them. These are made by burrowing crayfishes.

This exercise should be studied in the fall and again in the spring.

REPORT

1. Make a classified list of all forms taken.
2. What ones were taken sweeping? Which ones were found in flowers. Which ones were found on the stems and leaves? Which ones were taken on the ground? Which ones were taken in flight?
3. What specific associations between plants and animals does your collection reveal?
4. How many animals in your list were active?
5. Which ones are nocturnal?

Exercise XXIX

A DEAD LOG ASSOCIATION

OBJECT: To determine the animals associated with a dead log.

DIRECTIONS: Locate a fallen tree in the woods and carefully examine its external surfaces for animal forms. Sometimes the whip-poor-will nestles on a dead log to rest during the day.

Remove, bit by bit, the adhering bark, examining every crack and crevice for small hiding insects. Look carefully beneath the bark also. Irregular carving of engraver beetles will immediately be seen.

With a hand axe, cautiously cut away the outer part and make sure that you secure existing animals.

Within the heart of the log you will find burrows of insects. In these you should find the makers of the runways and others that merely use them.

Dependent upon the season and disintegration of the log you will find such animal forms as: ants, spiders, wood lice, termites, sowbugs, centipedes, millipedes, "glowworms," beetle larvae, and possibly adults of longhorn beetles, click beetles, passalid beetles, stag beetles, fungus beetles, cucujid beetles; pupae, cocoons, and others. Hollow logs may reveal rabbits, skunks, snakes, toads, salamanders, and numerous other animals.

Preserve all material collected for laboratory classification.

REPORT

1. Make a list of the animals likely to be found in dead wood.
2. List those which merely seek temporary shelter.
3. List the permanent residents.
4. What animals undergo only a part of their development in dead wood?

5. Make a cross-section of the log, showing the relative positions on and in it of the various animals observed and collected.
6. Will the kind of wood affect the assortment of insects which inhabit the log?

Exercise XXX

THE LIFE IN A POND

OBJECT: To study the animals of still water and to observe their distribution, habits, and adaptations.

DIRECTIONS: Ponds are interesting situations in which highly specialized associations are to be found. Like the animals themselves, ponds are individual in their makeup. They may be rain fed or spring fed, old or new, stagnant or comparatively fresh, deep or shallow, turbid or clear, concealed or exposed. Some will have steep banks with overhanging trees, while others may have gently sloping shore lines. These are usually bordered by marshes and exhibit a remarkable succession of vegetation from the hardwood and truly terrestrial plants to the emergent sedges, rushes, pickerel weeds, spatterdock, the floating duckweed, lily pads and upper leaves of submerged elodea, chara, ceratophyllum, potamogeton, brasenia, vallisneria, etc.

This study should include as many different kinds of ponds as possible and each pond should be studied thoroughly. Make several studies of each if time permits.

If the pond is large, it would be well to make an outline map of it and to note the surroundings.

Collecting stations should be established in order to make the distributional studies comprehensive.

As you approach the pond, note the succession of vegetation. Is there a distribution of plants according to the bank, sloping

shore, muck at the water's edge, the shallow water and deep water? Capture as many flying forms as possible. Dragonflies and damselflies will be most conspicuous.

Look for surface forms such as whirligigs, water striders, small whitish collembolae, and spiders. Are these in particular places such as exposed surface or among emergent plants?

Examine the emergent and floating plants. You should find the adults and larvae of Galerucella, Donacia (beetles), and other forms. On the under sides of lily pads and on submerged portions of other plants you may find snails, caterpillars, water newts, rotifers, sponges, eggs of various kinds, midge tubes, cocoons enclosing beetle eggs, and numerous other forms, dependent upon the season. In the spring the milky white masses of salamander eggs will float on the surface.

With the dip net drag some of the submerged vegetation to the shore and examine it. Crustaceans, water scorpions, dragonfly and damselfly nymphs, water beetles, water bugs, salamanders, water snails, etc., should be found in numbers by the careful student. Place a mass of these plants in mason jars and cover with water. In the laboratory you will find many small animals that would ordinarily escape observation in the field.

With a heavy dipper lift some of the bottom muck and spread it on the bank. Extreme patience and care must be exercised in examining this because so many forms are small and others are mud colored. A careful examination will reveal small mussels, dragonfly nymphs, midge larvae, leeches, scuds or benders, beetles, bugs, snails, mosquito larvae, cranefly larvae, backswimmers, water boatmen, beetle larvae, diving spiders, cyclops, cypris, crayfishes, tubifex (worms in tubes), and many others including bloodworms (Chironomidae).

Take some muck back to the laboratory in mason jars for the aquarium observations.

Throw out a tow net and draw it ashore three or four times. If possible use a boat and secure as many necton animals as you

can with the tow nets and dredge nets. You will probably capture sunfish, catfish, and other pond fishes.

Place a glass-bottom bucket in the water among the submerged plants and note the forest-like arrangement of plants and the characteristic associated animals. Collect as many different forms as possible, keeping some alive in mason jars for the laboratory aquarium.

General Observations. Note the quantity and distribution of pond vegetation. Collect specimens of all plants present. Place them in a 5% solution of formaldehyde.

Note the distribution of animals with respect to vegetation zones, depth, exposed areas, etc.

If the pond is deep, note the clarity of the water and the distribution of life according to the penetration of light.

A polished disc on the end of a graduated rod will enable you to determine the depth to which light penetrates. Lower the disc in the water and note the depth at which it disappears. Draw it upward and record the depth at which the disc reappears. The mean of several readings will indicate the transparency of the water.

Place some floating twigs on the surface of large ponds to detect currents.

In deep ponds temperature may affect the distribution of animals. Record the surface and bottom temperatures. Bottom temperatures may be accurately determined by placing a thermometer in the cork of a wide-mouthed bottle or jar. Fill the jar with water and insert the cork with the thermometer. Lower the jar to the bottom and allow it to remain there for three or four hours until the water surrounding the thermometer bulb in the jar is the temperature of the bottom stratum. This prevents a change in the thermometer when it is lifted to the surface.

The materials placed in alcohol in the field may be sorted more easily in the laboratory by dumping the vials of material into shallow white enameled developing trays.

REPORT

1. Make a classified list of pond animals.
2. Do the pond forms exhibit any marked adaptations?
3. Is there a distribution according to depth, turbidity, temperature, current, submerged vegetation, surface, exposure, shade, shore, bottom?
4. Make a drawing of a cross-section of a pond showing distribution of animals collected.
5. Describe the life histories, locomotion, respiration, and protective devices of the animals collected.
6. How does the pond association compare with the stream association?
7. Do young ponds have a large, fixed association?
8. What factors affect pond associations?
9. How are the various pond animals adapted to dispersal?
10. List the water plants present and indicate where the various species are found.

Exercise XXXI

ANIMALS OF RAPID BROOKS

OBJECT: To study the fauna of a rapid brook and to compare these animals with those of still and sluggish waters.

DIRECTIONS: Visit a rapid brook. You will find a variety of situations in each of which there exist characteristic animals. Note the nature of the shore vegetation and the extent to which it conceals or shades sections of the stream.

If the brook is an intermittent one, the fauna will be less fixed and extensive than in a permanent one.

There will be waterfalls, permanent pools, rapids, intermittent pools, and small shore bays. In each of these you will find interesting animal forms.

It is well to study a section of the brook which includes as many types of situations as possible. The time of year will determine the number and kinds of animals to be found.

At the brink of and on the face of the waterfall, search carefully for those animals that live in the rapid rush of water. Some will be found in the crevices concealed by falling water. Collect as many animals as possible and record their exact locations. Stonefly nymphs and black fly larvae will predominate.

In the large pool at the base of the falls you should find larger stream fish, mussels, large and small water beetles, and possibly giant water bugs.

In the rapids and swift running water, by examining the sides and under surfaces of stones, you will discover numerous kinds of animals such as mason-building caddisfly larvae, net-building caddisfly larvae, mayfly and stonefly nymphs, water pennies, freshwater flatworms, darter fishes, brook trout, miller's thumbs or blobs, dobson-fly larvae, crayfishes, salamander eggs (Eurycea), cranefly larvae, and the salmon-colored eggs of the miller's thumb (in spring).

In the less rapid water near the shore, water beetles, burrowing damselfly nymphs, snails, midge larvae, tadpoles, and water bugs abound, and water striders patrol the surface.

Toss some sticks into the stream along the shore and at different distances toward the middle of the stream. Note the speed of the current at the various distances. Where is the flow the most rapid? Is there a distribution of the fauna according to current? The rate of flow can be determined by recording the time it takes a floating object to travel a measured distance.

In the back bays where the water is comparatively still, whirligigs gyrate on the surface, while beneath the surface water boatmen, snails, backswimmers, tadpoles, and salamanders hold forth. On the under sides of stones you will find the small, branched colonies of Bryozoans.

To get all forms you should use the bottom scraper and drag the

bottom upstream. A hand screen made of copper fly screen tacked on two long handles is an excellent collecting device for swift streams. The screen should be spread and held by both handles with the lower edge of the screen on the bottom. Other collectors can overturn stones and disturb the bottom upstream. The forms exposed will be swept into the screen.

Additional specimens may be secured from the brink of the falls by holding the dipper at the crest and disturbing the bottom just above the brink.

REPORT

1. Is a rapid brook likely to have a different gaseous content than a still pond?
2. Do you suppose that this partly determines the life in an aquatic situation?
3. What are the means of (*a*) locomotion, (*b*) respiration, (*c*) resistance to swift water—of the animals you have found?
4. Describe the life histories of the animals collected.
5. Do the burrowing forms have well-developed swimming apparatus and streamline forms?
6. How many of the animals listed are larval or nymphal stages?
7. How many of them are aerial in the adult stage?
8. How many of them have you found in still water?
9. How do these animals collected capture their food?
10. How many are negatively phototropic?
11. Do any of the animals select the shaded sections of the brook?
12. List the animals collected according to the locations in which they were found.
13. Draw diagrams showing the distribution of the life in a brook.
14. Compare the fauna of the brook with that of a pond and creek.

Exercise XXXII

COMMON WATER ANIMALS

OBJECT: To fix the identities of some common water animals.

DIRECTIONS: In the chart on page 69 is a list of the commonest water animals. These should be well known to every student.

Prepare the following information about each animal and draw those marked with an asterisk. For those marked with double asterisks include drawings of the larva and adult.

1. Where found
2. Life history (metamorphosis)
3. Specialized adaptations (swimming, breathing, vision, adaptive radiation of legs, antennae, etc.)
4. Food
5. Interesting habits
6. Classification
7. Which stages are aquatic and which terrestrial?

Hand the report and drawing of each animal to your instructor. He will place his initials in the square after each animal, when your report is accepted.

Exercise XXXIII

STREAM FLOW REACTIONS

OBJECT: To observe the streamline form and rheotropic responses of animals of flowing water.

DIRECTIONS:

I. Make a wooden trough 24" × 6" × 4" and place three small rectangular pieces of wood ½" square at the ends and 5" long at

COMMON WATER ANIMALS

Student's name	Cypris *	Cyclops *	Daphnia *	Bender or scud *	Fairy shrimp *	Water sowbug *	Crayfish *	Hydra *	Leech	Flatworm	Snails 4 kinds
Approved by											

Student's name	Fresh-water mussel	Tubifex	Midge larva *	Cranefly larva	Horsefly larva	Blackfly larva *	Water penny	Dobsonfly larva Hell-gramite **	Dytiscid beetle **	Hydrophilid beetle **
Approved by										

Student's name	Caddis-fly larva and case *	Dragonfly damselfly nymphs **	Stonefly naiad **	Mayfly naiad *	Giant water bug *	Lesser water bug *	Water scorpion *	Marsh strider *	Back-swimmer *	Water-boatman *
Approved by										

Student's name	Whirligig beetle *	Toad	Frog	Salamander (Triturus) (Eurycea)	Catfish	Stickleback fish	Sunfish	Miller's thumb	Minnow (dace)	Turtle (painted)
Approved by										

intervals in the trough. This gives a ripple effect to the water. Place a piece of fine mesh screen across one end of the trough and incline the trough slightly toward the screened end. Put the elevated end under a hydrant and turn on the water enough that a fair current of water passes through the trough. Secure some stream animals such as mayfly nymphs, stonefly nymphs, water pennies, flatworms, darters, etc., and place them in the trough with their heads down stream. Observe their reactions to the current. After testing these reactions, increase the flow and note how all of the animals orient themselves. Increase the flow considerably and note which animals can remain fixed and which ones are washed "down stream."

II. Secure a tin dishpan and a small 6″ saucepan. Fill the small pan with gravel and place it in the center of the larger pan. Fill the larger pan with water to a depth of 3 or 4 inches. Place some stream animals in the water and with a small wooden paddle stir the water until a strong circular current is produced. Note the reactions of the animals. Reverse the current and note the effects. Place some caddisfly larvae in the pan with some fine sand and broken mica. Note the utilization of this material by the larvae in making their cases.

REPORT

1. What body shape seems best adapted to resisting currents?
2. Describe the orientation of animals in the current.

Exercise XXXIV

AQUARIUM STUDIES

OBJECT: (1) To observe the factors involved in the maintenance of balance of chemical conditions between plants and animals. (2) To observe the factors involved in the sustenance of

water life. (3) To determine the interrelationships which establish an association of water animals and effect distribution within a pond. (4) To observe the development of various water animals.

DIRECTIONS:

I. Prepare several small aquaria by placing a layer of washed sand in the bottom of tumblers or pint jars. Partially fill each container with water and plant a spray of Elodea, Cabomba, Myriaphyllum, Anacharis, Ceratophyllum or Sagittaria in the sand and allow it to stand for a day. Then tiny fish, water snails, bloodworms, mosquito larvae, or other small forms may be added. Do not place too many animals in one of these small aquaria.

Single forms may be raised through their entire life histories and single specimens of larger beetles, water bugs, water scorpions, etc., may be kept in these for observation for a day or two. They may be fed by placing flies on the water.

II. The class may construct several larger, rectangular aquaria for the purpose of observing "balance" and interrelationships.

A layer of clean washed sand should be placed in the bottom of the tank. The sand should be sloping toward one end for the purpose of making it easy to clean the aquarium from time to time. A layer of fine washed gravel should be placed on top of the sand. Add water until the tank is about half full. In adding water it is best to place a piece of cardboard or the back of the open hand on the layer of gravel and then pour the water on the card or hand. Otherwise the even contour of the bottom material will be destroyed.

Then insert sprays of water plants such as Vallesneria and Ludwigia in addition to any of those already mentioned. It is best to group the plants at the ends of the tank. This leaves a clear space in the middle for observations. Then fill the tank. Floating plants such as duckweed or water hyacinths may be placed on the surface.

To balance the aquarium it is best to allow the water to stand for a day or two. Then add goldfish, minnows, sunfish, or catfish,

the number being dependent on the size of the tank. A few water snails should be added because most of these feed on the algae that ordinarily grow on the sides of the tank and frequently obscure vision from the sides.

If the fish hover at the surface, it is an indication that there are too many animals for the amount of plant material and it is best to add some fresh water and either remove some of the fish or add more plants.

When the fish swim about freely and appear at ease, the aquarium is balanced and if kept under the proper conditions it will not be necessary to change the water.

Several things must be borne in mind in the preparation of a perfectly balanced aquarium. The tank should not be allowed to remain in direct sunlight for any length of time. Too much light promulgates the rapid growth of algae. Changes in temperature do not affect native animals in the aquarium but the water *can* get too warm and freezing will break the glass walls of the tank.

A glass cover, raised slightly at the corners to allow ventilation will reduce the rate of evaporation and keep out dust.

If algae grow too rapidly on the glass, add more snails. Snails will lay their eggs in jelly masses on the sides of the aquarium. These may be examined through a magnifier each day and the entire development observed.

To clean the aquarium, a piece of rubber tubing may be used to siphon off the waste which gravitates to one end in the sloping bottom.

These directions apply to permanent aquaria. Many kinds of fish may be kept in this way if temperature conditions are kept favorable. For tropical fish it is best to hang an electric light over the tank.

Most stream fish and goldfish can be fed on granular fish food. A mouthful of food per day will keep a fish active and healthy. When daphnia can be cultured or obtained, it is advisable to use them, at least occasionally, for food. Ground beef and beef liver,

meal worms, earthworms, etc., may also be used. Excess food particles should be removed within two hours after feeding.

Two "don'ts" should be emphasized. Don't overfeed. Many people lose their goldfish because of overfeeding.

If it becomes necessary to change the water, *make sure that the temperature of the fresh water is about the same as that which is removed.* Fish can withstand gradual changes of temperature but sudden changes usually have fatal results.

III. In one of the larger tanks place some of all the kinds of water animals you have collected.

Keep a record of the number of each kind added and observe results. Some will feed on others and eventually exterminate them. Stream forms will die from lack of oxygen. Others will not find suitable bottom conditions and others may be affected by the higher temperatures of laboratory aquaria.

Observe the positions assumed by the various animals. Note stratifications, distribution, locomotion, burrowing habits, etc.

Obstruct the light from one end or an end and a side of the tank and observe the movements of the animals. If the tank is in a dark place, hold a light at one end.

Cover the top, ends, and sides with cardboard, leaving two equal openings on the sides. Then lift the card from the top and determine the distribution within the tank.

After one to two or three days, check the numbers and kinds of animals remaining in the aquarium. Check again after a week and at regular intervals thereafter until the association of animals is fixed.

Measure the hydrogen ion concentration and oxygen content of the water twice each day if possible. A La Motte indicator set is inexpensive and efficient.

Suspend a thermometer in a corner of the tank and record the temperature twice each day during these studies.

IV. Place a counted assortment of animals in a battery jar and record the temperature of the water after a few hours. Place

sufficient ice in the water to suddenly lower the temperature considerably. Do any of the forms cease activity or die? Keep the water very cold for a day and observe any changes in behavior. How many of the specimens are still alive?

REPORT

1. Describe the life histories of forms raised.
2. Describe the distribution of forms in the mixed aquaria (bottom, attached to plants, surface, burrowing, attached to sides, free swimming, etc.).
3. Describe the locomotion of animals observed.
4. Which animals are predatory?
5. Which ones die apparently from lack of suitable conditions? Compare the conditions in the aquarium with the normal habitats of these forms. Suggest the cause of death.
6. Which animals go to the surface for air? How do they get it?
7. Which animals are truly aquatic?
8. What are the various adaptations for breathing under water, swimming, capturing food?
9. What animals are crawlers?
10. Which ones are protectively colored? How?
11. Which ones have "streamline" forms?
12. Describe the exchange of materials between plants and animals in aquatic situations.
13. After three days what animals had disappeared?
14. What animals constituted the final fixed association?
15. List the causes of disappearance of missing forms.
16. Summarize your observations on the behavior of the various animals.
17. Is there any connection between the pH and O_2 content and the disappearance of animals?
18. Were temperature changes sufficient to be a factor in mortality?

19. What were the phototropic responses of the animals to light? Which were positive and which were negative in their responses?

Exercise XXXV

PLANCTON ORGANISMS

OBJECT: To become familiar with the minute animals and plants of lakes and ponds and to determine their active movements.

DIRECTIONS: Drag fine-mesh plancton nets through the water and carefully wash all material collected into quart mason jars.

Collections should be made in the morning, at noon, after sunset, and about ten o'clock at night. When possible, collections should be made on bright, moonlight nights and the material collected should be compared with that obtained on a dark night.

The data should include the relative quantities of material taken in all collecting periods.

With the plancton sorters separate the animals and plants and examine the various sets with binocular magnifiers.

The material can be largely identified by using the references suggested. Ward and Whipple's *Freshwater Biology* is recommended. Others are suggested in the text. Living material can be quieted by adding a 1% solution of chloretone to the water in the watch glass in which specimens are placed for examination with a binocular magnifier. The more common forms will include daphnia, cypris, cyclops, Leptodora, and flagellates. Diatoms and other microscopic plants should also be found. The kinds and numbers will depend upon conditions and seasons.

Sketch: daphnia, cyclops, cypris, Leptodora, and a few other forms.

REPORT

1. What classes of animals constitute the plancton fauna?
2. What class predominates?
3. What indications of phototropic responses do your studies suggest?
4. What adaptations do plancton forms have to swimming and flotation?
5. What evidences of vertical migration have you found?
6. Are plancton animals adapted to active or passive migration?
7. What relationship exists between plancton animals and fishes?
8. Are the microscopic plants as motile as the animals?

Exercise XXXVI

CARRION INSECTS

OBJECT: To acquaint the student with the animals attracted to excrement and carrion.

DIRECTIONS: Many insects such as flies and beetles are eaters of and breeders in excrement and dead animals. The adults of these are frequently seen in places far removed from their birthplaces. A careful study will reveal their habits and life histories.

I. Place some excrement or the disintegrated body of a bird, mammal, or other animal on a woodland trail and wait for visiting animal forms. Note the time lapse between the planting of the material and the first visitors. Keep careful records of the different animals, their numbers, and successional appearance.

II. Place some fish heads in quart mason jars, securely tying some cheesecloth over the opening of the jars. Make a small slit in the cloth covering. Take the jar to a woods or field near the woods and place the jar in an excavation with the top just flush with the surface of the ground. Pack dirt around the jar and loosely

cover the top with dead leaves. Hang a strip of white cloth in a conspicuous position, so that the location of the trap may easily be found again. The trap should be placed in the late afternoon.

III. Secure a large kitchen sieve or colander and fill it with sand. Then place the carcass of a dead mouse, bird, or fish on the sand. Or place some fresh excrement on top of the sand in the container. Place the container in an excavation in the ground with the level of the sand flush with the surface of the ground. This trap should also be placed late in the day and its position well marked.

Allow the traps to remain over night. The next day visit the traps and examine them for animal forms. If no animals are present, it is probably because the material is not putrid enough to be odorous and the traps should be left undisturbed and visited later. One trap should be left planted long enough for the animals to have started on their development. Later visits will yield larvae and pupae.

The animals in the jars may be taken with forceps and placed in a mixture of formaldehyde and alcohol.

The sand trap should be taken to a stream and the sand washed out completely through the mesh. The animals caught will remain in the container. These should be placed in a mixture of formaldehyde and alcohol. After a few days they should be placed in strong alcohol to which a few drops of formalin and glycerine have been added.

You will secure maggots, adult flies, beetles (Histeridae, Silphidae, Staphylinidae, Scarabaeidae, Dermestidae) and other insect forms.

IV. Place a dead mouse on the ground in the evening and cover it with crossed sticks so that prowling animals cannot carry it away. Look for the carcass the next day. With a trowel lift the earth where the carcass was placed. Look for animals beneath the buried mouse. You should find orange and black sexton beetles.

REPORT

1. What animals are attracted to carrion?
2. What is the basis of this attraction? Chemical response?
3. Describe the breeding habits of the various forms taken.
4. Are these forms active during the day?
5. How do sexton beetles bury the carcass?
6. Why do they bury it?
7. In what way are carrion insects beneficial?

Exercise XXXVII

SUBTERRANEAN ANIMALS

OBJECT: To become familiar with some animals that live underground and to observe their adaptations to subterranean existence.

DIRECTIONS: The subterranean fauna constitutes a distinct stratum of the animal world. The animals themselves are interesting and they exhibit some remarkable adaptations.

I. Examine a mole which is a typical underground animal. Note the shape of the body, the length of the legs, modifications of the fore feet for digging, shape of the head, absence of eyes and ears, and the lack of countershading. Rub the fur forward and backward. What advantage or adaptation does this suggest?

II. List other mammals that live underground and describe their adaptations.

III. Select a plot of rich soil and measure a small area ($12'' \times 12'' \times 6''$). Remove the soil and transfer it to a bucket. Examine it carefully for insect larvae and other conspicuous forms. You should find "grubs," wireworms, ants, earthworms, and pupae of moths and flies. After the larger visible forms are taken from the earth, put water in the bucket and stir the mud.

Decant the water into clean jars and note the small worms—mostly round worms. Are there many of them? Collect and record all living things.

IV. Examine gopher, rat, groundhog, and other burrows for subterranean animals which seek shelter in them.

This exercise may be given as a class assignment.

V. Classify subterranean animals according to:

1. Those that live almost entirely underground.
2. Those that dig for shelter only.
3. Those that dig for food.
4. Those that use the burrows of other animals.
5. Those that undergo a part of their development in the ground.

REPORT

1. Are there distinct characteristics adapted to subterranean existence?
2. What modifications for digging have cicada larvae, scarab beetles, mole crickets, groundhogs, gophers, earthworms, sphinx caterpillars, digger wasps, spiders, ant-lion larvae, ants, turtles, may beetle larvae?
3. What larger forms conceal the entrances to their burrows? Which ones do not?
4. How do chipmunks conceal their homes?
5. What are the responses of subterranean animals to seasonal changes?
6. What animals hibernate in underground burrows?
7. Discuss the food, habits, and coloration of the woodchuck or groundhog.
8. Do subterranean animals have large ear and eye openings? Why?
9. Are short legs advantageous to subterranean animals? How?
10. Do subterranean animals have or need protective coloration?

Exercise XXXVIII

CAVE ANIMALS

OBJECT: To study the animals of caves.

DIRECTIONS: If there is a cave within a reasonable distance, the student of field zoölogy should, by all means, visit it. The usual precautions of chalking one's way so that egress will be facilitated, and of having reliable lights, food, drinking water, etc., should be taken.

Before entering a cave, examine the region around the entrance for evidences of animals which may inhabit it. Tracks, débris, and excrement are usually found. Foxes, bears, raccoons, skunks, opossums, rabbits, deer mice, snakes, and even wildcats sometimes seek the shelter of caves.

Cave forms, while not abundant, are interesting and exhibit some remarkable adaptations.

Bats seek the caves for hibernation and for resting during the day in summer. They cling to the walls and ceiling. Wood rats or cave rats may be detected by the piles of sticks which they collect. As a rule, the rats themselves are not shy and may be readily observed in the light from an electric flash.

Examine the ceiling, walls, and floors for Thysanura, spiders, roaches, cave crickets, beetles, etc.

If water is present, use a wire dipper of fine mesh and collect several jars of material for later examination. Use the flash and look on and under stones for crayfishes and other animals.

REPORT

1. List the cave animals you have seen and taken.
2. Use the references and add other forms to your list.
3. Do cave animals have conspicuous eyes?

4. What adaptations to living in darkness have cave animals?
5. Which animals found in caves are permanent residents and which are only temporary residents?
6. Suggest the sources of cave animals.
7. What types of interrelationships probably exist among the forms you have taken?
8. How do cave animals find their food and each other?
9. What physiological adjustments to limited food supply are characteristic of cave animals?
10. How are caves formed?
11. Where are the great American caves?
12. Are the appendages of cave insects modified for any special purposes?
13. In general, what can you say of the coloration of cave dwellers?

Exercise XXXIX

ANIMALS FOUND ON OPEN BEACHES

OBJECT: To become familiar with the animals to be found on sandy beaches.

DIRECTIONS: Beaches vary in width and extensity and each kind may have a variety of situations, with characteristic associations. This exercise is somewhat general and is to an extent all-inclusive except for the studies of the smaller drift line, which constitutes a separate exercise.

Collect all animals possible. This will necessitate a close scrutiny of all débris, as well as examination of logs. Look under stones and other objects which might afford temporary shelter.

Flies and carrion beetles will be attracted to the dead fish and other animals washed ashore. Tiger beetles patrol the beach. Small carabid beetles are usually active in the pebble line.

Termites frequently inhabit logs at some distance from the water edge. Terns, gulls, plovers, and sandpipers forage on wide beaches. The nests of these are commonly found. Ladybird beetles, ground beetles, and numerous other insects hide under stones and bits of débris.

In the damper level sand the burrows of tiger beetle larvae may be seen in numbers. Probe these with small forceps and extract some larvae.

On wider areas numerous insects, dead and alive, may be found. These represent, usually, those forms washed on to the beach by the waves. In their attempts to reach the vegetation zones, they succumb to the intensity of the sun, exhaustion, or they fall victims of predatory animals. The remains of many of these (wings, legs) are to be found. Examine them and attempt to identify them.

Collect as many flying forms as possible.

Make a record of all observations on specimens collected together with the usual data. Be sure to indicate if the beach is rocky or sandy.

REPORT

1. List some animals to be found on sandy beaches.
2. Which of these are accidental inhabitants?
3. Which animals are the real inhabitants?
4. How do the different animals get there?
5. What interrelationships (predatism, etc.) have you observed?
6. Which animals are typically nocturnal?
7. Where were these found?
8. What distributional factors are involved in a beach association?
9. What are the sources of the beach fauna?

Exercise XL

ANIMALS FOUND IN THE DRIFT LINE

OBJECT: To become familiar with the animals characteristic of the beach drift and to determine the sources of the fauna, as well as the interrelationships of the animals in a drift association.

DIRECTIONS: Visit a beach in the morning (the earlier the better) and observe the irregular line of débris deposited on the sand by the waves. A casual observation reveals little or no activity.

Examine the material very carefully, a little at a time, spreading the finer material so that no forms will be overlooked.

Collect as many animals as possible and record the activities and interrelationships you observe.

In the laboratory classify and label all specimens.

REPORT

1. What animals are to be found in beach drift?
2. How many of these were washed up by the waves?
3. How many probably came to the beach from surrounding land areas?
4. What attracted the latter forms?
5. Are these forms nocturnal or diurnal?
6. Do you suppose the activity in the association would be accelerated at night?
7. How many of the animals collected probably sought the protection of the débris during the day?
8. Are the latter really an active part of the association?
9. Would the list of animals in beach drift be virtually the same day after day and month after month? Why?

Exercise XLI

ANIMALS OF THE SEASHORE

OBJECT: To become acquainted with the marine animals commonly found on beaches and also the terrestrial residents and visitors.

DIRECTIONS: Check the various zones and strata of the ocean beach in the classifications of habitats. Visit the beach in early morning, noting whether it is narrow or broad; rocky or sandy; open or exposed. Note also whether the tide is in or out. The beach should be visited at both high and low tides. As you approach the water, look for dolphins, sharks, or other sea dwellers in the waters offshore. In the shallow water look for starfishes, sea urchins, sponges, corals, sea weed, worms, clams, and snails. In the drift line or on the open beach look for jellyfishes, horseshoe crabs, echinoderms, mollusks of many kinds, sponges, corals, sea lilies, and shells harboring hermit crabs. Fiddler and edible crabs, numerous other crabs of various sizes, sand dollars, and a host of other animals will be found, especially after storms. Look for burrowing animals. Numerous carrion insects will be attracted by dead fish; myriads of small bivalves will come in with the waves and quickly disappear; worms of various kinds; numerous birds; and, at night, roving animals may be seen.

Make a record of everything you see. List every form taken or observed and classify it as far as possible with the use of your textbook and references. Arrange your list according to the stratum in which each animal was recorded.

REPORT

1. Which animals are beach dwellers?
2. Which are victims of the waves?
3. How many animals recorded are strong swimmers?

4. Where do the marine forms normally live? On the bottom? In deep or shallow water? Floaters?
5. Which ones burrow in the sand?
6. Which ones in your list live beyond the high tide level?
7. Which ones live in the intertidal zone?
8. Which ones are on the beach voluntarily?
9. How do the fauna of rocky and sandy beaches differ?
10. Which animals utilize structures made by others?
11. What animals in the list are predators?
12. What are the means of locomotion of the various beach forms?

Exercise XLII

SAND DUNES AND THEIR INHABITANTS

Note: This exercise should be studied, when possible, at regular periods throughout a course, season, or year.

OBJECT: (1) To become familiar with the animals of sandy areas and to determine the bases of the association. (2) To ascertain the periods of activity of dune animals and observe their interrelationships.

DIRECTIONS:

I. Visit a sand dune area and record observations on its extent, exposure, and vegetation.

Collect all the animals you can and record in your field notes the birds, larger animals, and tracks you see.

Carefully examine the vegetation for associated forms. Collect the aerial forms such as flying Orthoptera, adult ant-lions, dragonflies, damselflies, robber flies, midges, etc.

Look for hiding forms under the low shrubs. Under logs, boards, and other objects you will probably find deer mice and their nests, lizards, ants and snakes (puff-adder, milk snake). Burrowing toads

remain buried in the sand during the day and emerge just after dark.

On the sand you should find the conical-shaped sand traps of ant-lion larvae, sand-colored spiders and grasshoppers, Syrphus flies, tiger beetles, digger wasps, and scraps of the shells of turtle eggs. Look for turtle nests.

You may need to make several trips before a representative collection can be made.

Prepare proper records for all forms collected. Classify all animals at once.

II. Visit the dunes on a sunny day and wait, at a point of vantage, for the resumption of normal activity. By keeping constantly on the alert you can observe the normal activity of the animal forms. Note feeding habits, predatory activities, protective coloration, nest building, etc.

This study, to be complete, should include a comparison of activities on sunny days and cloudy days. It should also include observations on the periods of activity *throughout* the day. This necessitates a trip to the area at dawn. Beginning with the break of day and extending until dusk, observations of the succession in which the characteristic animals begin their activities should be made. With each note the time and climatic conditions should be recorded. In this way you will determine the periods of activity of the various dune animals and ascertain their responses to light intensities, etc. Extended studies of this kind can be more easily worked out as class problems and if observers work in relays.

A similar study which will be quite as interesting can be made at night. Electric flashes can be used to examine the active forms.

REPORT

1. What animals are characteristic of sandy areas?
2. Which ones are most common and which are least commonly found?
3. Which forms seem to be dominant?

4. Which are predatory?
5. Which ones burrow in the sand?
6. How many of the animals in your list are active at the same time?
7. Which ones are protectively colored?
8. Which ones are sedentary?
9. How do dune animals respond to the intense sun of midday?
10. What is the extent of the activity periods of the various animals?
11. How does general activity of the animals on cloudy days compare with the activity on sunny days?
12. Are there certain periods in the day during which individual forms are active?
13. Does wind affect the activity of any animals in the association?
14. What animals in the association are crepuscular or nocturnal?
15. Are nocturnal animals active *all* night?
16. Is the activity on a moonlight night more or less general than on a dark night?
17. How do nocturnal animals see? How do they find each other?
18. What part does sound, luminescence, odors, etc., play in the behavior of nocturnal animals?

Exercise XLIII

NOCTURNAL ANIMALS

OBJECT: To study the habits of nocturnal animals.

DIRECTIONS: At least one trip should be devoted to the study of the animals which constitute the nocturnal horde.

The trip should be made to a woodland or to a neglected field bordered by a rather dense wood. The class should be equipped with flashlights, killing jars, insect nets, vials of alcohol, and forceps. A powerful light or two and a strip of white muslin or

cheesecloth should be supplied by the instructor. The cloth can be stretched in front of the lights and used as a light screen. Another strip of cloth should be placed on the ground at the base of the screen if possible. This will make it easier to find beetles and other insects which fly against the screen and drop to the ground.

The trip to the collecting ground should be made before dark and the swifts, bats, nighthawks, and other forms which begin activity at dusk and continue until dark can be seen and recorded. As darkness approaches, the insects, salamanders, toads, snakes, birds, and mammals should be sought. Ripe bananas, molasses mixed with a little vinegar, a mixture of beer, molasses, and yeast, and cheap perfume can be used to attract moths and other insects if placed on the trunks of trees.

The class should be as quiet as possible and remain on the lookout for poisonous snakes which are active at night. Use the light screen (auto lights serve admirably), examine the baited trees, and using the flashlights examine the trunks of trees, the ground stratum, and all other situations for active creatures. The bases of trees and the surrounding ground should also be examined thoroughly. Capture flying and crawling forms. Moths, beetles, bugs, crickets, roaches, and numerous other insects will be found. Examine the foliage for feeding insects. Snakes, lizards, salamanders, frogs, toads, mice, flying squirrels, rabbits, raccoons, opossums, wildcats, house cats, and various other larger animals can be seen.

Collect and record all living things. Note the time, weather conditions, and other factors. There is a distinct succession of nocturnal animals with a well defined periodicity of activity. Dark humid nights will reveal a different set of creatures and activities than can be seen on a bright moonlight night. A warm night will show a greater activity than a cold night.

The type of activity, the exact location of each animal taken or observed and its reaction to light, should be noted. Calls, luminescence, odors, and other devices which nocturnal animals

have for locating each other and for warning others of the approach of danger should also be noted and interpreted when possible. Do the animals have bright or dull colors? The animals which have reflecting eyes should be indicated in your field notes. When stones are lifted, the momentary flashes of certain collembolans may be seen if lights are extinguished. Stones should not be overturned with the bare hands in sections where poisonous snakes are to be found. The time of year will affect the nature of your observations.

Kill and preserve your material in the usual ways.

Keep an accurate record of your finds.

REPORT

1. What animals are active at dusk?
2. What nocturnal leaf-eaters were observed?
3. Do your records show a definite activity period for each of the animals observed or collected?
4. Do nocturnal animals have warning calls?
5. Which ones had glowing eyes?
6. Which insects were attracted to your lights?
7. Which animals were found only through careful searching?
8. What was each observed form doing?
9. What factors might alter or determine nocturnal activity?
10. How do nocturnal animals find each other?
11. What adaptive features have flying squirrels, wildcats, skunks, owls, and the other nocturnal animals for capturing food?
12. How did the mosquitoes find you? How do they locate each other?
13. What is the general coloration of nocturnal animals?

Exercise XLIV

THE CLAY BANK ASSOCIATION

OBJECT: To become acquainted with the animals that select a clay bank for their abodes.

DIRECTIONS: Visit a clay bank and, as you approach it, look for openings which might suggest animal caves.

The larger openings are probably nests of bank swallows or kingfishers if close to a stream.

Smaller openings should reveal wasps, bumble bees, spiders, tiger beetles, bristle tails, slugs, snails, and occasionally cave crickets. In the summer, spiders may be seen holding their cocoons up to the sun at the entrance of the burrow.

Gather as many animals as you can. Classify and label them. Be careful in investigating the wasps which build their nests in clay banks.

REPORT

1. Are there any animals in your collection that have not been found in other situations?
2. Is there a typical clay bank association?
3. Are the animals found sedentary or are they active predators?
4. How do the bank dwellers make their burrows?

Exercise XLV

ANIMAL COLORATION

OBJECT: To evaluate certain colors and color patterns in respect to their defensive functions.

DIRECTIONS: Make a list of all the animals in your collection and include other forms observed in the field. Classify them according to the following characters:

Coloration

I. Conspicuous
   1. In both sexes
   2. In males only (goldfinch, some beetles, etc.)
   3. Associated with stings, poisons, etc. (coral snakes, skunks)
   4. Flash and signal warnings (vesper sparrow, white-tailed deer, etc.)
   5. Changing colors—seasonal, background (weasel, tanager, chameleon)
   6. Relation to light
   7. Mimics of dangerous or inedible animals (viceroy, etc.)

II. Inconspicuous
   1. On snow (weasels, arctic hares, snow owls, etc.)
   2. On bark (bark moths, tree frogs, etc.)
   3. On leaves (caterpillars, plant lice, mantises, etc.)
   4. On barren ground (wolf spiders, toads, etc.)
   5. On dead leaves (grouse, quail, chipmunks, etc.)
   6. Among grasses (sparrow, female redwing blackbirds)
   7. In forests (spotted or striped pattern of fawns, etc.)
   8. Ruptive markings (camouflage)
   9. Open plains (uniform colors)
   10. On twigs, etc. (walking-sticks, caterpillars, etc.)

Make a list of animals (all kinds) with protective coloration.

REPORT

1. Suggest the function of sex differences in color.
2. Is there such a thing as "warning coloration"?
3. Is there a relationship between stings and poison and bright colors?
4. Do fishes, amphibians, and lizards change color? How is this affected?
5. How does countershading benefit an animal?

6. Are cave, subterranean, and noctural animals brightly colored? Why?
7. Write a paper on the part color plays in the lives of animals.
8. Distinguish between pigmental and structural colors.
9. What factors effect color production in animals?
10. Do you know of any evidence of color discrimination in animals?
11. Does color play a rôle in plant survival?

Exercise XLVI

DEFENSE MECHANISMS IN PLANTS AND ANIMALS

OBJECT: To correlate structural processes with protection afforded to plants and animals by them.

DIRECTIONS: From your list of local animals and plants select the forms which are protected by the following. Add other examples.

I. Animals
   1. Horns or antlers (deer, cattle, etc.)
   2. Odors (skunks, weasels, stinkbugs, lace wing, millipedes, bombardier beetles, etc.)
   3. Stinging hairs (saddle-back caterpillars, hydra)
   4. Poison glands (snakes, toads, etc.)
   5. Claws (crayfishes, hawks, owls, wild cats, bears)
   6. Modified hairs (porcupine, armadillo, etc.)
   7. Shells (snails, mussels)
   8. Stings (scorpions, bees, wasps, ants)
   9. Biting jaws (waterboatman, backswimmer, centipedes, gila monster, spiders, foxes, bears, snakes, etc.)
   10. Color pattern (mole, whip-poor-will, etc.); warning color (skunk)
   11. Luminescence (firefly, jellyfish, protozoans)

II. Plants
   1. Hairs (nettle, mullein)
   2. Odors (skunk cabbage)
   3. Thorns and spines (rose, horse nettle, holly, hawthorn, chestnut, cactus, etc.)
   4. Poisons (ivy, laurel, Euphorbia, poison sumac)
   5. List other defense structures of plants and examples.

REPORT

1. Write a paper on animal defense.
2. Why must plants defend themselves?
3. Would flight be considered a protective mechanism?
4. How are defensive structures used by the various animals?
5. How efficacious are defense mechanisms?
6. Are defense structures ever restricted to one sex?
7. Are they ever adornments?
8. How do sponges, corals, worms, toads, birds, centipedes, crabs, flatworms, radiolarians, and rabbits defend themselves?
9. Is plant defense as conspicuous as animal defense?
10. Do you suppose that structures on plants and animals were developed purely for defensive purposes?
11. What part do physiological processes play in defense of organisms?

Exercise XLVII

THE SIMPLEST PLANTS (ALGAE)

OBJECT: To determine the principal characters of one-celled and related simple plants; and to compare these with other plant groups including desmids, diatoms, and lichens.

DIRECTIONS: Among the simplest of the one-celled thallophytes are *Chlamydomonas* and *Carteria.* These are ciliated or

flagellated, unicellular, motile plants found in ponds. *Chlamydomonas* is more common and bears two cilia, while *Carteria* bears four cilia (flagella). Both are members of a large group of colonial, green algae (Volvocales).

I. *Carteria* has a firm cell wall which encloses a cup-shaped chloroplast or chromatophore in which the nucleus can be seen. The four cilia pass through the cell wall from the top of the nucleus. At the bases of the cilia are two contractile vacuoles which pulsate rhythmically. A structure called the pyrenoid, which often contains a sheath of starch grains, lies in the basal part of the chloroplast and a pigment spot can be seen at the top.

Reproduction takes place by the division of the protoplast into two or four daughter cells within the original cell wall. Each daughter cell carries its own cilia. These daughter cells are called zoöspores and finally break through the cell wall of the parent cell and then grow to normal size. These movements and developmental stages can be observed by studying living cultures. The cilia can be seen by adding a weak iodine solution to a slide on which cells are placed in water. Sometimes the mother cell produces eight smaller and more motile cells which unite in pairs (conjugation). These gametes lose their cell walls and their nucleii fuse together. This is known as isogamy.

II. *Ulothrix* is a filamentous or thread-like alga found attached to rocks in cool running water. It is held in place by a single, weak, colored cell called a holdfast. It is the common form which makes the rocks slippery in brooks. An examination of Ulothrix shows that it is an unbranched colony of cells, some of which produce as many as 16 zoöspores which escape through a small pore in the side of the cell. Each zoöspore bears four cilia and swims about rapidly for a time and then attaches itself to a stone, elongates, and by transverse fission produces a new colony.

III. *Spirogyra* (pond scum or frog spit) is also a filamentous alga in which the chloroplast is a broad, ribbon-shaped structure running spirally around the cell. The pyrenoids appear as a series

of small, rounded areas. The nucleus is suspended in the center of the sap cavity by cytoplasmic threads which extend to the cell wall.

Two filaments which lie side by side send out projections or conjugation tubes until their tips touch each other. The cell wall then breaks down and the protoplasmic content of one cell enters the other. The living structures fuse into a thick-walled zygospore which remains at rest for a time. Occasionally two adjoining cells in the same filament unite in a similar manner.

IV. *Desmids* are also unicellular plants commonly found in ponds. They are the most ornate of these lowly organisms, often exhibiting a variety of form and color. Some species have spines and other protuberances as well as distinct markings. The cells of desmids are composed of two symmetrical halves separated by a zone called the isthmus. The desmids are somewhat similar to Chlamydomonas and they reproduce by binary fission and by conjugation in which two protoplasts unite.

V. *Diatoms* are most certain to be encountered in studies of water from ponds. They are varied in shape and many of them are quite motile. The cell wall is rather hard and siliceous and consists of two halves. One half fits over the other in telescope fashion. Each cell usually contains two chloroplasts. The cell divides by fission, each half carrying away one-half of the original wall (shell) and regenerating a new one. Sometimes a zygote is formed by the union of two escaped cells.

VI. *Lichens* are commonly found on soil, trees, rocks, and recumbent logs. Many of them are beautifully colored. A study of a few local species is recommended. Inasmuch as the types are variable, texts and manuals should be consulted in connection with their study. The principal types include: (1) the crustose which grow flattened against an object or substratum; (2) the foliose which are more loosely attached and some of which are leaf-like in structure; and (3) the fruticose which seem to have a main stem with erect or pendant parts.

Note: The instructor can expand this exercise to include many more thallophytes such as red and brown algae, rusts such as the apple rust and wheat rust, mildews, puff balls. In all cases the principal emphasis should be placed on the identifications of groups and their methods of reproduction.

REPORT

1. In what ways do the one-celled plants resemble animals?
2. What is the color of the one-celled plants examined? Does this suggest specialized nutritional processes?
3. In a plankton association, what interrelationships exist among and between plants and animals?
4. Do the one-celled plants bear any relationship with higher plants?
5. Where do motile one-celled plants occur? Why?
6. How do lichens reproduce?
7. Does the motility of one-celled plants suggest a property of protoplasm?

Exercise XLVIII

SIMPLE PLANTS–FUNGI (THALLOPHYTA)

OBJECT: To study further the Thallophytes.

DIRECTIONS: The fungi constitute another large and diverse group of the simpler plants. They are distinguished from the Algae by the absence of chlorophyll. Most of them are parasitic or saprophytic and they include the bacteria, slime molds (Myxomycetes), the alga-like fungi (Phycomycetes) such as watermolds, blights, downy mildews; the sac fungi (Ascomycetes) such as mildew, yeast, and morels; and the basidia fungi (Basidiomycetes) such as smuts, toadstools, and rusts.

I. *Bacteria.* A culture of decaying leaves and stems should reveal colorless, rod-shaped (bacillus), curved or spiral (spirillum), and spherical (coccus) types of saprophytic bacteria. Can you observe the essentials of cell structure?

II. *Alga-like fungi.* Moisten a slice of bread and cover it with a dish, allowing it to remain without light for several days. The familiar bread mold will develop. Examine a strand or mycelium of the mold under the microscope and note the (1) erect branches which bear globular sporangia at their tips, (2) short branched rhizoids or hyphae which anchor the mold colony, and (3) the transverse stolons or hyphae.

The spores are produced in the sporangia. Break open a ripened sporangium and examine the spores. A germinating spore produces a protruding filament or hypha. The branching hyphae are called mycelia (singular, "mycelium").

III. *Sac fungi.* These include yeast. Place yeast in a culture medium of potato water and sugar. After a day in a warm place, the culture will have the well-known yeast odor and bubbles of gas can be seen rising in it. The whitish substance in the brine of dill pickles will provide ample material for immediate study. Examine the yeast under the low power of the microscope. Determine how many cells there are in an individual plant and note the reproduction by budding. Are the daughter cells of similar size? How are yeasts similar to bacteria? In what ways are they different?

IV. *Basidia fungi.* The common field or meadow edible mushroom (Agaricus campestris) or the commercial species (Psalliota campestris) can be used to demonstrate the features of the basidia fungi. Cut sections through the gills of a mushroom and study the section under the microscope. On the gills note the club-shaped cells or basidia. Each basidium is the swollen terminal cell of a hypha and usually bears four basidiospores. These are supported on slender stalks called sterigmata (singular, "sterigma"). The spores are produced in the basidia and these

are arranged in a fruiting surface or hymenium. In a mature mushroom, carefully remove the stem. Place the cap on a piece of paper and tap lightly. Carefully lift the cap and note the arrangement of the spores. Spore prints of numerous species can be made in this way by using photographic or other sensitive papers. The spores can be germinated by dusting them on rich, moist soil and keeping in the dark for several days.

REPORT

1. Are there ways or characters which postively distinguish poisonous from non-poisonous mushrooms?
2. What human diseases are caused by fungus plants?
3. If fungi lack chlorophyll, how do they manufacture or secure sustenance?
4. Describe the life histories of chestnut blight, wheat rust, and white pine blister disease. How are these diseases controlled?
5. What is the function of intermediate hosts?
6. How do simple plants compare with simple animals with respect to: cell structure, differentiation of protoplasm, motility, colonial organization, and reproduction?

Exercise XLIX

MOSSES AND LIVERWORTS (BRYOPHYTA)

OBJECT: To recognize mosses and to interpret their habits.

DIRECTIONS: Mosses are Bryophytes and are therefore related to the liverworts. They may usually be distinguished from the liverworts by growing erect and having stems. The liverworts are usually prostrate, producing a flattened thallus with upper and ventral surfaces. Both the liverworts and mosses have complex life histories involving an alternation of generations.

The identification of species is a matter for botanists and we are concerned here with only the general structure of these plants. The mosses can hardly be identified without fruiting stalks which are not always available. The fruiting stalk is leafless and bears a capsule.

Examine a plant of Polytrichum or other common moss and note the spiral leaf arrangement on the slender stem. No roots are present but the plant is held in the soil by delicate, thread-like rhizoids.

Examine a leaf under the microscope and note that it is just one or two cells thick. Some of the leaf cells may be dead but they are constructed so as to absorb and hold water.

The plant bears two sets of multicellular sex organs. The male plant may be recognized by a cup-like structure at the tip of the stem. This consists of closely packed leaves. Squeeze the contents of the cup into a drop of water on a slide and examine under the microscope. Note the long, sac-like antheridia or male organs which usually possess hairs or cilia. The antheridium consists of a stalk and jacket. Within the jacket are produced numerous male gametes which possess two cilia and are quite motile.

The sporophyte is the reproductive plant and bears a capsule on the leafless stalk. Crush its contents into a drop of water and examine the spores with a microscope. Germinating spores produce branching filaments called protonema. From the protonema arise the stems of the plant.

Spores are normally discharged from the capsule and give rise to the protonema which produce other plants asexually.

The sporophyte is produced by the archegonium or female organ which is flask-shaped. After fertilization is effected, the spore capsule is sent up on the slender stalk.

Alternation of generations is demonstrated by the production of the sporophyte and the successive generations arising from the protonema.

Compare a liverwort such as Riccia or Marchantia with a moss.

Riccia is a common inhabitant of ponds and lakes, while Marchantia is found in bogs.

REPORT

1. In what ways are mosses similar to flowering plants?
2. How do mosses differ from lichens?
3. Do mosses grow on live trees? Rocks?
4. What is Spanish moss?
5. Are mosses parasitic? Saprophytic?
6. Are all mosses green?
7. What are: Sphagnum? Peat moss? Club mosses?
8. How do sperm reach the eggs?

Exercise L

THE STUDY OF A FERN (PTERIDOPHYTA)

OBJECT: To become familiar with the growth and habits of ferns.

DIRECTIONS:

I. Examine a common fern. Does it have a stem above ground? Are the leaves simple or compound? The curled, hairy fronds are new leaves. Remove the plant and note the underground stem. What is its nature? Examine the under sides of the leaves. Some of them will have rust-colored dots. What is their position in relation to the veins? Are they numerous? These are called sori. Scrape a sorus onto a glass slide with a knife. Mount the sorus on a slide in water and examine it under the microscope. Note the helmet-shaped structure called a sporangium. The ring which surrounds the sporangium is called the annulus. Is the wall of the annulus of uniform thickness? The spores develop within the sporangium. What part does the annulus play in the

discharge of ripened spores? Place a cover glass on the sorus and gently press downward on the cover until the sporangium breaks. What does it contain? The leaf which bears the sori is called a sporophyll.

The prothallium is a flat plate of cells formed by the germinating spores. What is the shape of the prothallium? Compare the upper and lower surfaces of a prothallium. How do they differ? The filamentous rhizoids appear as roots. The small, globular antheridia and the brown bottle-shaped archegonia can be seen on the under side of the prothallium. Attempt to see the contents of these under the microscope. Swimming antherozoids can usually be seen in the antheridia. It would be well to examine prepared longitudinal sections of an antheridium and archegonium. Draw the prothallium showing location of rhizoids, antheridia, and archegonia.

How is fertilization effected? The embryonic plant is a sporophyte. If possible, study a young sporophyte which is still attached to the prothallium. From what has the embryo developed? It is composed of a primary leaf, a primary root, and is attached to the prothallium by a small foot-like structure embedded in the cells of the prothallium. The stem is almost invisible. Are the gametophyte and sporophyte the product of sexual reproduction?

II. *Equisetum.* The common horsetail is another Pteridophyte commonly found along railroads and bordering cinder beds. The sterile plant is bushy and the fertile plant bears a cone or strobilus at the top. Note the underground stem from which the aerial plants arise. What kinds of leaves are present on the sterile plant? How are they arranged? How does the fertile branch differ from the sterile? Draw both the sterile and fertile plants.

Examine the cone or strobilus and note the central axis on which the spore-bearing sporophylls are borne. Examine a sporophyll under the microscope. The elongated sac-like structures on the

under side of the sporophyll are sporangia. Crush a sporangium and examine the dry spores under the microscope. Gently exhale your breath on the spores. What happens? Note the spiral bands or elaters attached to the spore. What is their function? How many bands are there on each spore?

The spores can be germinated and the prothallium examined. Note the antheridia and archegonia as on the fern.

Club mosses such as Lycopodium and Selaginella can be studied in a similar manner.

After making this study in the laboratory, the common local species of ferns and club mosses should be collected for identification.

REPORT

1. Summarize the complete life history of a fern.
2. Draw the stages in the development of a fern.
3. Where do most ferns grow?
4. How does a fern differ from a moss? A flowering plant?

Exercise LI

THE STUDY OF A HIGHER PLANT

OBJECT: To become familiar with all of the general features of a plant.

DIRECTIONS: Select a low herbaceous plant such as a weed, clover, or some other small (preferably flowering) plant. Carefully remove it from the ground, being careful to get the roots.

I. Examine the roots. What kind are they? Is there a primary root? Are secondary roots present? In which direction do the parts grow? Are root hairs present? What is their function? Compare the roots with a radish, carrot, grass, sweet potato, and hyacinth.

II. Examine the stem. What is its shape in cross-section? How are the leaves arranged on the stem? Are the leaves above one another? Are there any other structures or markings on the stem? Is the stem branched or forked? Compare with a morning glory, bindweed, pole bean or pea, English ivy, rose, mint, and the main trunk of a tree. Record the differences among these. Are there many branches? What seems to be the function of the stem?

III. The leaves are respiratory. Examine the leaf and note the shape, the stem or petiole, midrib, veins, margin, and blade. Compare with the leaves of corn, smilax, maple, elm, linden, rose, and geranium. What are the differences in color, shape, margin, and venation? How do the leaves of the locust, buckeye, ash, fern, ailanthus, and vetch differ in these respects? Which are simple? Which are compound? Pinnately compound? Palmately compound? How are they arranged on and attached to the stem?

IV. Flowers. Are the flowers in clusters, distributed along the stalk, or borne singly? Are they borne on many stalks or few? Compare Queen Anne's lace, dogwood, iris, snapdragon, wisteria, morning glory, dandelion, locust, catalpa, buckeye, barberry, laurel, corn tassel, cypripedium, boneset, joe-pyeweed, and dog-tooth violet with respect to the types of flowers. What is inflorescence? What flower families are represented in the above list? Are the above flowers perfect, pistilate, or staminate? Are the plants monoecious or dioecious? Which are wind pollinated? Which are pollinated by insects? Which ones are brilliant? Which ones grow in conspicuous places? Is there a relationship between color and habitat? Are the petals united or separate? Are the sepals united or separate? Are the flowers fragrant? Are the petals striped?

The teacher can substitute a completely different list of more common local flowers for the above list.

V. The fruit. In the above list of plants, determine the fruits according to the following characters. Is the fruit naked or en-

closed? If enclosed, what is the nature of the covering? How many parts is it composed of? How many chambers? How are the seeds attached? Is it brightly colored? Edible? Is it sought by birds or insects? How is it adapted to dispersal? Is the fruit fleshy, aggregate, a berry, nut, achene, drupe, explosive, adhesive, tufted, or winged? Compare the fruits of tumbleweed, mulberry, spanish needle, coconut, apple, wild cherry, milkweed, hazelnut, beech, oak, walnut, chestnut, catalpa, viburnum, papaw, wild pea, osage orange, bitter nightshade, burdock, snapdragon, jewelweed, dogwood, and others. What is the primary function of the fruit? List the ways in which plants are disseminated. How are elm, ash, linden, cottonwood, maple, and pine seeds distributed? In the plants mentioned above, indicate those in which seeds are dispersed by animals, wind, or water.

REPORT

1. In a plant are organs developed internally or externally?
2. How does this differ from organogeny in animals?
3. How can a plant be identified as a living organism?
4. What is the most important part of a plant?
5. Could plants survive without animals?
6. How are unripe fruits protected?
7. How are the flowers adapted for pollination?
8. What is dimorphism in flowers?

Exercise LII

ROOTS

OBJECT: To study the structure and function of roots.

DIRECTIONS:

I. Preliminary preparation. Place a parsnip in water colored with red ink. Germinate some radish seeds between moist blotting paper. A carrot or parsnip can be used for the general study.

1. What kind of a root is this? Are branches present? What are they? Draw the root as it is seen.

2. Cut the stained root lengthwise through the middle and locate (a) the outer skin or epidermis, (b) the cortex beneath the epidermis, (c) a division layer separating the cortex from (d) the central cylinder, and (e) fibers and ducts in the central cylinder. Branch roots may be seen emigrating from the central cylinder through the cortex and epidermis. Draw the longitudinal section, labeling all parts.

3. State the functions of each part.

4. Make a drawing of these parts in cross-section.

II. Study the tips of the roots on the radish seedlings with the lower power of the microscope. Make a drawing about two inches wide and five inches long of the tip showing the following structures: (a) root cap; (b) epidermis (note the cell thickness); (c) the cortex (compare with epidermis in thickness); (d) the central cylinder; (e) the ducts and fibers running lengthwise in the central cylinder; and (f) the growing point at the lower extremity of the central cylinder.

III.—1. If prepared slides of root hairs are avaliable, examine them with high and low power. Recall the studies in connection with cell structure.

2. With a hand lens or low power examine the root at a point where the root hair is attached. What is its origin?

REPORT

1. How does a root hair perform its function?
2. What part does osmosis play in root function?
3. How does a root compare with a stem in structure?
4. In the roots examined, which are primary and which are secondary roots?
5. How do the roots of grass, corn, dahlia, and radish seeds compare with the parsnip?

6. Do all plants have roots?
7. How do roots respond to soil conditions such as moisture and nutriment?
8. What common roots are edible?
9. Which are used as medicine?
10. In what common plants is nutrient stored in the roots?
11. What are tubercles? On what kinds of roots are they found?

Exercise LIII

STEMS

OBJECT: To determine the characters of the stems of plants.

DIRECTIONS: Secure 8-inch terminal sections of the stems of buckeye, sweet gum, linden, walnut, or other trees. Also stems of corn and geranium.

I. Note:

1. The nodes, indicated by the leaf scars. Are the scars prominent? Note the markings of the vascular bundles on the scars. How many are there? Are the scars opposite, alternate, or whorled? What does this indicate?

2. The corky dots on the stem. What are these? Are they regularly arranged?

3. The annual rings. These are ring scars or scale-scars which occur at irregular intervals and the distance between the groups of rings represents a season's growth.

4. Buds. Where are they located? Is there a terminal bud?

5. Draw the stem showing all structures.

II. Examine a thin cross-section of a stem with a microscope and locate the pith. What is its shape? Note successively the xylem, medullary rays, cambium, phloem, bast fibers, and epidermis.

Draw the stem in cross-section, showing the various regions in color.

1. Make a longitudinal section of several stems by splitting them lengthwise through the middle. Note the arrangement of structures. If a stem is placed in colored liquid for several days and studied in longitudinal section, what parts are most highly colored? What does this indicate? Make a drawing of the longitudinal section of the stem locating the regions in color.

2. Examine cross-sections of the stems of geranium and corn. Compare them with the other plants examined. Draw the cross-section of a corn stem showing all regions and structures in color. Where are the duct bundles most numerous? Where are they largest? Are they in regular rings?

3. If a thin cross-section of a large stem is available, compare it with the cross-section of the twig. How many annual rings are there? What are the radiating lines?

REPORT

1. Through what sections of the stem do liquids rise and descend?
2. Distinguish between exogenous and endogenous stems.
3. Distinguish between excurrent and deliquescent stems.
4. What are herbaceous plants?
5. What are the functions of lenticels?
6. What is pith? Do all woody plants have pith in the twigs?
7. What is the significance of the branching in conifers?
8. What structural features have water plant stems?
9. What causes the "grain" of lumber?
10. Compare the dicotyledonous and monocotyledonous stems with respect to growth, structure, and function of the outer covering.

Exercise LIV

BUDS

OBJECT: To study the structure of leaf and flower buds.

DIRECTIONS:

I. Select a forked twig of the buckeye or horse chestnut and note the location of the buds—lateral and terminal. Are they opposite or alternate? What relations have the buds to leaf scars and branching? Are the buds the same size and shape?

II. Do they represent two kinds of buds? How does the leaf bud differ from the flower bud if present? What effect has a flower bud on the branching and growth of the twig?

III. On what part of the stem are the lateral buds best developed? Why?

IV. Select and draw a large bud (X_4). Is it a lateral or terminal bud? Is it scaled or naked? Is it smooth or sticky?

V. Describe the arrangement of the scales. Are they opposite or alternate? How are they arranged in comparison with those beneath them?

VI. Remove the scales in pairs and arrange them one from each pair in the order in which they are removed. How many pairs are there? How is each pair placed with reference to those above and below? What changes in appearance of the scales can you notice toward the center of the bud? Are there any veins in the scales? Are the inner scales as sticky as the outer ones? Is the inner surface of the last scales woolly? Why?

VII. Are there evidences of leaves in the bud? Compare a terminal bud with a lateral one. What structures are found in the terminal bud that are not present in the lateral bud?

VIII. Draw a longitudinal section of a terminal bud, labeling all parts.

IX. Place a twig in water and observe the opening of the buds.

REPORT

1. What becomes of the bud scales when the bud develops?
2. What kinds of buds produced the ring scars on the twig?
3. How is the bud protected from cold and insects?
4. Is bud arrangement and leaf arrangement the same? How does this arrangement compare with branching?
5. Are terminal buds always present?

Exercise LV

LEAF STRUCTURE AND FUNCTION

OBJECT: To study the structure, forms, and functions of leaves.

DIRECTIONS:

I. Secure the leaves of any common plants such as lily, corn, rose, English ivy, wandering jew, plantain, pine, spruce, hemlock, and grass. Selecting a broad leaf, make the following observations:

What is the flat portion of the leaf called? Does it have a stalk? What is it called? Do all leaves have stalks? Note the margin or outer edges of the leaf. What are its characteristics? Note the tip and base of the leaf. How would you describe them? Are there scale-like structures at the base of the petiole? If so, what are they called? Is there a midrib? Note the veins; how are they distributed in the leaf? Compare with a lily or corn leaf in this respect. How does your leaf compare in shape, venation, and general structure with the other leaves mentioned above? Make a drawing of the leaf showing all parts and structures.

II.–1. Remove a portion of the epidermis from the under side of a leaf and place it on a glass slide. Cover the section with water and place the slide under the low power of a compound microscope. Note the cellular structure of the section. Are the cells

regular in size and arrangement? At intervals note the slit-like openings or stomata through which transpiration takes place. On either side of the opening note the two guard cells which surround each stoma. How do these guard cells compare with the other cells of the epidermis?

2. Compare a section of epidermis from the upper side of the leaf with that of the under side. Are the cells similar? Can you find stomata on both surfaces? On which surface are stomata most numerous?

3. Examine a cross-section of a leaf and note:
   a. Upper and lower coverings or epidermis.
   b. Palisade cells just below the upper epidermis. What is their shape? What do they contain?
   c. Spongy tissue which constitutes the principal internal cellular content. Note the shape of cells and the irregular intercellular spaces.
   d. Veins may be cut at various angles according to the venation of the leaf used. Is the vein constructed like a stem or a portion of it?

III. Place a growing plant under a bell jar and note the collection of moisture on the jar the next morning. What does this suggest? What structures does the moisture come from? Test the air in the jar with a lighted match. Is the presence of oxygen or carbon dioxide indicated?

IV. Place some leaves of the rose or other plant in boiling water. Transfer them to a 95% solution of alcohol to extract the green pigment. To the extract add an equal quantity of benzol, xylene, or pure gasoline, and shake vigorously. If the pigments do not separate, add a drop of water and shake again. Repeat the process until results are obtained, shaking after each drop of water is added. The green chlorophyll should form an upper layer in the solution and the bottom layer should be yellow due to the presence of carotin and xanthophyll. Note the effects of transmitted and reflected light on the chlorophyll. This is called fluorescence.

Place some chlorophyll solution (extracted above) in two test tubes. Cover one tube with black paper and expose them to strong sunlight for some time. What happens?

V. Clip some strips of black paper, tin foil, or disks of cork over sections of leaves of a laboratory plant. After four or five days examine the covered portions. How do they compare with the rest of the leaves and with the uncovered portions? How does the covered portion compare with the color of seedlings grown in the dark? Indicate your observations in a sketch drawing.

REPORT

1. What is the function of the leaf?
2. What is photosynthesis? How is it effected?
3. What makes leaves change color in the autumn?
4. Distinguish between simple and compound leaves.
5. Why are stomata on the under side of the leaf?
6. What determines the rate of transpiration?
7. How are leaves arranged on a plant?
8. What are the functions of the interspaces in the leaf?
9. How do the inner cells get moisture and carbon dioxide?

Exercise LVI

PHOTOSYNTHESIS

OBJECT: To determine the processes involved in photosynthesis.

DIRECTIONS:

I. Select a leaf that has been partially covered to exclude the light. Dip it into boiling water and then extract the chlorophyll with warm alcohol, leaving the leaf in the liquid for several hours. Wash the leaf thoroughly and brush iodine over the surface.

Does the iodine indicate the presence of starch in the whole leaf? Where is starch absent? Why?

II. Test a mushroom for starch. Compare the inner and outer leaves of cabbage and head lettuce with respect to starch content.

III. Place some submerged elodea, anacharis, myriaphyllum, cabomba, or other water plant under a funnel with the stem of the funnel upward. Place a test tube or bottle over the stem of the funnel and expose the plants to sunlight or a bright electric light. Note the bubbles rising in the stem of the funnel. After several days remove the bottle and quickly insert a glowing taper into it. What happens? Where did the oxygen come from? Would the same results be obtained if the apparatus were kept in the dark? Why?

REPORT

1. What is the function of chlorophyll in photosynthesis?
2. Where does the carbon dioxide come from?
3. How is the starch manufactured and utilized by the plant?
4. Would the introduction of carbon dioxide in the water have hastened the collection of oxygen?
5. Write the equation for photosynthesis. Is it a reversible equation?
6. How does the oxygen experiment compare with respiration?

Exercise LVII

FLOWER STRUCTURE

OBJECT: To become acquainted with the details of flower structure.

DIRECTIONS: Select a common flower such as a lily or trillium and dissect it carefully, keeping the component parts of each set of structures together. A complete flower is composed of the following sets and parts:

1. The *receptacle* is the expanded portion of the stem which bears the flower. All of the flower sets are seated in the receptacle.

2. The *calyx*, the green (usually) outer cup in which the conspicuous parts of the flower are seated. The calyx is composed of leaf-like parts called *sepals* which may or may not be united. How many sepals are there?

3. The *corolla* or usually brilliantly colored part of the flower. It is composed of *petals* which are frequently distinctly separated but sometimes fused together as in the trumpet flower and morning glory. How many petals are there? Are they all alike? Are stripes present or is the color uniform?

4. *Stamens* which are reproductive structures. They lie within the whorl of petals and bear the pollen. The stamen is composed of the pollen-bearing structure called the *anther* which is variable according to species. The anther is borne on a slender stalk called the *filament*. How many stamens are there? Are they fused together or distinct? Examine the pollen under the microscope. Sprinkle some pollen on the surface of a glass or tube of sugar water and keep it in a warm place for a day or two. Note the extension of the pollen tube. What is its function in fertilization?

5. The *pistil* (or pistils) is in the center of the flower. How many pistils are there? Do the stamens surround the pistil? Note the tip of the pistil which is rough and sticky when ripe. This is the *stigma* to which pollen adheres. The elongated, stem-like portion of the pistil is the *style*. The enlarged basal portion is the *ovary* in which seeds are borne and which becomes the fruit of the plant. Note the divisions of the ovary. These are the *carpels*. How many are there? Cut an ovary lengthwise and another one crosswise. What is the shape of the cross-section of the ovary? In the cut section note the ovules. How and where are they attached? Is there any relation between the numbers of components of the various flower parts such as sepals, petals, stamens, carpels, etc.?

Drawings should be made of the flower and ovary in cross-

section and in longitudinal section. All parts should be properly labelled.

Several kinds of flowers should be studied. They should include pistillate, staminate; papillionaceous flowers (pea, snapdragon); minute flowers; a wind-pollinated flower; composites such as dandelion; dogwood; nasturtium; iris; and the flowers of maples, willows, and the catkins of poplars. In each kind of flower, the various structures should be identified. The arrangement of parts with respect to cross-pollination should be observed.

REPORT

1. What is the function of the flower?
2. For what purpose do color and odor serve?
3. How do wind-pollinated and insect-pollinated flowers differ?
4. How are unwelcome visitors excluded from flowers?
5. Describe the pollinating devices of the laurel (Kalmia), berberry, milkweed, and iris.
6. Illustrate the following types of flower clusters: spike, raceme, head, umbel, panicle, cyme, and corymb.
7. What characteristics have the composites?
8. Do the flowers of monocotyledons and dicotyledons differ in structure?
9. What is the predominant color of night-blooming flowers? Of alpine flowers?
10. What other common plants belong in the same family with the potato?
11. To what family of plants does the apple belong?
12. Does a flower die after pollination?

Exercise LVIII

THE SEED

OBJECT: To study the details of a seed and to determine the origin and growth of a seed plant.

DIRECTIONS:

I.—1. Examine some dried lima beans and note their shape. Find the oval scar which indicates where the seed was attached in the pod. This is called the hilum. Near the end of the scar locate a minute opening called the micropyle. Note the membranous covering of the seed. Draw the seed (X6) labeling the external features.

2. Soak some beans in warm water for several hours and then remove the outer coat. Note that the covering has a thin, delicate inner layer called the tegumen and an outer testa. Separate the seed into its halves. These are cotyledons or seed leaves. Between the cotyledons on the concave side is the embryo. It consists of: (1) an upper or terminal bud, the plumule; (2) the hypocotyl which is the primitive stem; and (3) a lower or distal end, the radicle which develops the root. Make a drawing (X6) showing location of embryo and its regions.

II.—1. Examine the kernel of corn, noting: (1) the outer covering; (2) the point of attachment; (3) the silk scar at the distal end; (4) the outline of the embryo on the side; and (5) a ridge indicating the plumule. Draw the seed and label external features.

2. Soak some corn in warm water for several hours and split a kernel lengthwise with a sharp knife. Is the seed composed of two halves similar to the bean? Moisten the exposed surfaces with iodine and observe the two general regions of the endosperm. How do they compare in size? In the embryo note: (1) the plumule, pointing toward the silk scar, (2) the hypocotyl below the plumule and pointing toward the point of attachment, and (3) the single cotyledon between the plumule and the hypocotyl.

Make a drawing of the longitudinal section of the kernel, labeling the regions of the endosperm and the embryo.

III. Plant some seeds of the lima bean, corn, and pea in light, moist earth or in moist sawdust and examine them in all stages of growth. Locate the cotyledons, hypocotyl, and plumule in all stages. Make drawings of all stages of germination and growth.

REPORT

1. What part of the bean plant is the pod?
2. What structures attach the seeds?
3. When a seed germinates, what part of the plant penetrates the seed coat?
4. How does water get into a seed?
5. What part of the bean seed comes up above the ground during growth?
6. What changes occur in the cotyledons of the bean during growth? What happens to them eventually?
7. What part of the corn seed first comes above the ground?
8. What becomes of the endosperm of the corn seed as it grows?
9. When do secondary roots appear during growth?
10. State several uses of cotyledons in seeds.

Exercise LIX

SPRING FLOWERS

OBJECT: To learn the flowers as they bloom in the spring and to study their names, habitat selectivity, adaptive features, and the legends connected with them.

DIRECTIONS: There are numerous illustrated books on wild flowers of all sections. Using the most available of these, identify the early flowers in the order of their appearance. A working knowledge of Gray's Manual should be developed also.

Such common flowers as hepatica, spring beauty, dog-tooth violet, blood root, anemone, jack-in-the-pulpit, skunk cabbage, and scores of others are found in a large section of the United States. Beginning just before the last snow disappears, look for wild flowers. Note the situation in which each species is found (such as ravine, marsh, damp woods, open field). Record the date and attempt to interpret the structural features with respect to pollination, attraction of visitors, methods of insuring fertilization, defense; and those structures which exclude unwelcome visitors. All flowers should be identified as to species and the species should be grouped into families.

A list of the native flowering plants, including trees and shrubs, in the order of their appearance and the situations in which they are found should be charted.

The common names frequently indicate legends and folklore and these should be ascertained when possible. The scientific name usually indicates characters, legends, geographical range, or medicinal value. The derivation of each name should form an important part of this study.

Other desirable information about the local flora can include: (1) range of color within families, genera, and species; (2) methods of pollination; (3) protective devices; (4) structural adaptations of parts or the whole plant; (5) geographical distribution of the family, genus, or species; (6) medicinal value, if any; (7) type of fruit and its dispersal; and (8) does the species or its relatives have any edible derivatives?

REPORT

1. What is the story of narcissus? yarrow?
2. What native flowers trap insects?
3. How is the closed gentian pollinated?
4. What holds skunk cabbage in the spongy soil?
5. How is iris pollinated?

6. What are dimorphic flowers?
7. What does the name *Helianthus decapetalous* mean?
8. What is the value of stripes on the petals of some flowers?
9. Are nectar glands of value in cross-pollination?
10. What are the relationships between insects and flowers?
11. Does color affect the type of visitor to a flower?
12. What insects pollinate clover? Trumpet flowers? What adaptive features have these insects?
13. Do brilliantly colored flowers grow in conspicuous places?
14. What common flowers grow in damp, shady places? Which ones grow in open fields?
15. What flowers grow in sandy areas? In rocky soil? In marsh land?
16. What flowers in your list are monocotyledons?
17. What is the first flower to bloom in your section?
18. What flowers in your list are perfect and possess both stamens and pistils?
19. Why are the composites considered to be the highest flowering plants?
20. How do desert flowers achieve their ends?
21. Do all flowers produce seeds?
22. What flowers in your list are annuals? Perennials?
23. Why are scientific names usually derived from Greek and Latin?
24. What are papilionaceous flowers? Name those in your list.
25. What common flowers belong to the rose family?
26. To what family do the bitter nightshade, potato, and tomato belong?
27. Why is the dog-tooth violet a lily?
28. What garden flowers are cultivated wild species?
29. What is the significance of each of the following names: Heliotrope? Liriodendron? Rhododendron? Erythronium? Sanguinaria?
30. Make a list of flower books.

Exercise LX

CARNIVOROUS PLANTS

OBJECT: To become familiar with some plants that devour animals.

DIRECTIONS: Secure specimens of sundew (Drosera), Venus' flytrap (Dionaea), butterwort (Pinguicula), pitcher plant (Sarracenia), and bladderwort (Utricularia).

I. Sundew is a small plant inhabiting bogs in the northern states. It has a rosette of reddish, rounded leaves, each of which is covered with hairs. The hairs on the margins are longer than those in the center of the leaf. Each hair is slightly enlarged or knobbed at its extremity and in the living plant each knob has a drop of sticky liquid. The glistening of these drops in the sunlight gives the plant its name. Insects attracted by the liquid are held fast and the surrounding hairs bend over the victim. These hairs secrete a protein-digesting enzyme which digests the insect. This may be demonstrated in the laboratory with living plants. Inorganic bodies such as splinters and grains of sand do not evoke a response.

Make a drawing of the leaf showing hairs and the manner in which insects are captured. Does the plant bear flowers? Does it produce seeds? Is it a higher plant?

II. Examine Venus' flytrap. Note the shape of the leaves and the marginal spines. Each leaf is composed of two oval shaped lobes which are hinged together at the midrib. Note the three bristle-like hairs on the upper surface of the leaf. These are sensitive and when an insect alights on the leaf the lobes close suddenly like a trap with the marginal spines interlocking to prevent escape. As in sundew, the captured insect is digested by protein-digesting enzymes secreted by glands on the surface of the leaf.

Draw the leaf in its normal, waiting position and also when the trap is closed. Describe the leaf arrangement, flowers, and geographical range of the Venus' flytrap.

III. Butterwort or Pinguicula is a plant that grows on wet limestone in the extreme northern section of the United States and Canada. It is small with a rosette of entire, sessile, fleshy, elliptical leaves. The leaves feel greasy to touch—hence the name butterwort. The upper surface of the leaf is covered with scattered hairs which secrete a sticky substance to which alighting insects adhere. When an insect is caught, the edges of the leaf curl inward to bring more hairs into contact with the victim. Between the glandular hairs are shorter, disk-like hairs which are thought to absorb digested proteins.

The single, purple flower is borne on a scape in early summer

IV. Pitcher plant. This plant grows in bogs throughout the northern states. It bears a cluster of pitcher-shaped leaves which terminate in a hood. The leaves are yellowish-green with numerous elongated purple markings. Each leaf becomes partly filled with water from the rains and insects crawl into the leaf from which they cannot escape because the inner surface is covered with downward-pointing hairs. Eventually the insects get into the water and drown, their disintegrating bodies providing nourishment for the plant.

If plants are collected, the water in the leaves should be poured into a beaker and examined carefully for aquatic larvae and then examined with a compound microscope for protozoans. Some of these organisms are indigenous to the pitcher plant alone.

V. Utricularia or bladderwort is a common inhabitant of ditches, pools, ponds, and lakes throughout a large section of the United States. The plant consists of numerous fine submerged leaves which bear small bladders. Each sac or bladder has an opening at one end on which can be seen a valve-like lid. Several inward-pointing bristles extend into the opening. Small larvae swim into the bladder and are trapped within. Examination of freshly col-

lected plants will usually reveal captured specimens. It is not definitely known to what extent, if any, the plant is nourished by the trapped specimens.

VI. Other carnivorous plants can usually be seen in conservatories.

REPORT

1. What would be the relationship between a plant that is nourished by captured insects and the insects themselves?
2. What kind of an association is it when the plant does not devour captured specimens?
3. Do insectivorous plants depend entirely upon captured forms for sustenance?
4. What are some other interrelationships between plants and animals?
5. To what families of plants do the above-mentioned carnivorous plants belong? How many are in the same family?

Exercise LXI

PLANT ASSOCIATIONS

OBJECT: To become familiar with the plant inhabitants of local areas and to determine the ecological factors involved in these associations.

Note: The student should prepare for this exercise by reading the discussions of plant associations in a textbook of Plant Ecology.

DIRECTIONS: It is obvious that every habitat situation harbors its own coterie of plant forms and that plants manifest a pronounced selectivity in habitat preferences. While an open meadow will reveal a different flora from a rock ravine, and the marsh harbors plants not found in deciduous forests, it must be remem-

bered that in addition to the conditions in each of these habitats, there are other factors involved in the localized distribution of plants. The differences are due to environment and to the adaptability to and toleration of environmental conditions. Geographical location, topography, and physiography of the terrain, climatic and biotic factors must also be recognized as influencing the plant life of every region. The measurement of these factors is beyond the scope of this exercise but their effects can be noted. The plants identified should be listed according to the strata (zones) in which each group is found. An outline map showing the location of the strata (zones) should be made. Each species should be indicated by a number and the numbers inserted in each stratum. The exact conditions of muck, water, or soil should be described in the field notes. All plants should be studied in each stratum. In every case the date and the condition of the plant (stage of growth, in foliage, flowering, etc.) should be recorded. A well-kept calendar of spring flowers will forcibly demonstrate seasonal succession. The following study (I) will indicate ecological succession.

I. A lake, a land-locked pond, or a stream will serve to demonstrate a pronounced succession of plants, provided the margins are undisturbed.

Zone 1. Identify the dominant plants in the woods some distance from the water. This is likely to be a climax association with hardwoods such as oaks and hickories being dominant.

Zone 2. Next to the shores the soft maple, elm, sycamore, and green ash or other softwoods will likely be encountered with honey locust, wild grape, and ivy associates.

Zone 3. Next study the marginal vegetation—that which borders the highest water level. In this the buttonbush, cottonwood, willows, alders, and others will be found.

Zone 4. In the swampy region which represents only occasional flooding but which is permanently swampy there will be another association including reeds, rushes, and skunk cabbage.

Zone 5. On the borders of this swampy section, next to the water and in the shallow water, the cat-o-nine tails, pickerel weed, arrow leaf, and many others will be found.

Zone 6. In the water along the shore, ditchweed, ludwigia, water-lily pads, smartweed, and a host of typically aquatic plants will be observed. Distinguish among emergent, floating, and submerged kinds in listing these.

Zone 7. In the deeper water (3 to 10 feet) you should find vallesneria, chara, potamogeton, brasenia and duckweed.

II. Study the plants in an evergreen forest, listing all trees, shrubs, and herbaceous plants.

III. Determine the plant association in an open neglected field, noting conspicuous colors and relative heights.

IV. Make a list of the plants in a ravine, noting dominant trees and shrubs, slope, nature of the substratum, exposure to the sun, and any other determining factors. Is this flora unique?

V. Chart the plants along a stream including marginal and stream bed species. There will be numerous factors involved here and close observation of structural features should be made and noted.

VI. Other studies of plant associations should be made when possible. These might include:

1. A bog
2. Sand dunes
3. A mountain slope
4. A desert
5. Winter greens—kinds and locations
6. Upland and lowland plants
7. A previously burned-over area
8. Roadside plants
9. Plants along a railroad

REPORT

1. What are the adaptive features of the roots in the plants confined to dry, medium dry, and wet situations?
2. Is plant distribution as characteristic as animal distribution?

3. Do environmental factors definitely determine plant associations?
4. Would the animal life present alter plant groups?
5. What are the specific determining environmental factors?
6. Can local distribution be interpreted in the same way as geographical distribution?
7. Are certain families of plants represented in all sorts of environmental habitats?
8. What is the dominant plant in each situation studied?

Exercise LXII

THE SCHOOL HERBARIUM

OBJECT: To prepare a collection of native plants for class study.

DIRECTIONS: The making of individual collections of flowering plants is to be deplored. Such practice results in the reduction of flowering plants, and in sections where it has been used for years the number of wild flowers is pitiably small. Wild flowers constitute a choice heritage and their protection should be the aim of all nature teaching.

A representative collection of native species, properly mounted and preserved, is a desirable teaching aid. The collection can be built over a period of years and used for teaching identifications.

In making a collection, the whole plant should be carefully removed from the soil. The roots should be washed and partially dried by pressing them between blotting paper. Then the whole plant should be carefully spread between blotting paper or several thicknesses of newspaper and weighted down in a warm, dry place until the specimen is thoroughly dried. It is sometimes desirable to dip the plant in a solution of bichloride of mercury before pressing. Inexpensive plant presses are sold by supply houses and

these are more desirable than the ordinary home-made methods used in pressing plants for mounting.

After drying, the plant should be placed on a stiff piece of white cardboard and secured by glue and small strips of paper. The cards should be of uniform size. It is best to cover the mounted plant with sheets of isinglass or cellophane. The name of the family, genus, and species, collector, locality and date of collection should be placed in uniformly sized lettering in the lower right corner of the card. A printed form is cheap and much more satisfactory.

The collection of plants should be arranged according to families and kept in cardboard boxes or in an herbarium cabinet. If the plants are well protected, they may be arranged for display in the classroom or laboratory. A typed list of plants in the collection should be posted and an attempt should be made to secure the flowers of summer and early fall. These the student rarely studies because of the closing of school in the spring. As a result, the student learns only the spring flowers and misses the plants which bloom during June, July, and August.

Such a collection can be used effectively in teaching local flora, seasonal succession, and midsummer recreational study.

Native plants which are uncommon or rare can be transplanted by the class to habitats in close proximity to the school where the living plants can be studied by classes.

Exercise LXIII

PLANT AND ANIMAL RELATIONSHIPS

OBJECT: To determine some of the relationships between plants and animals.

DIRECTIONS: The relationships between plants and animals are numerous and infrequently indiscernible. Studies in the field

to date have revealed that animals use the plants as food, for shelter, and for making their homes.

Those relationships frequently result in modifications of both the plants and animals and sometimes mutual benefits are derived from the associations (symbiosis). Animals already observed mimic twigs, leaves, and bark, and some of them are structurally adapted to life in the trees or on leaves and stems of all plants.

Some plants such as sundew, pitcher plants, and utricularia even catch insects, while many plants resort to unique methods of defending themselves against unwelcome relationships.

This exercise is to reveal the extent to which plants and animals are dependent upon each other and how antagonisms and beneficial relationships affect the lives of the individuals involved. The exercise requires patience and alertness but a thorough attempt will prove worth while.

Spend an hour on a clear summer day observing the visitors to a particular kind of flower—touch-me-not, buckeye, daisy, goldenrod, iris, or any other kind of spring, summer, or fall plant. Has the flower a bright color and strong odor?

Count the number and kinds of visitors. Observe all of the activities of the visitor such as feeding, foraging, ovipositing, etc. How long do the visitors linger? When possible, observe the approach of the visitor. Catch as many visitors as you can as they leave the flower. Examine the bodies of the captured forms. Pollen will adhere to hairy coats and is carried by bees in pollen baskets. Pollen clips of milkweed will cling to the feet of flies and other visitors.

After you have finished your observations, tear the flower apart and look for hidden residents.

On your return from the trip, note the seeds that adhere to your clothing (spanish needles, beggar's ticks, hounds' tongues, burrs, etc.). Do these suggest another type of animal and plant relationships? Collect these seeds and place them on cards with glue or in seed or Riker mounts.

REPORT

1. How many visitors came by air? How many by crawling up the stem?
2. Do all visitors seem to have profited by their visit?
3. What attracted the visitors? Odor? Color?
4. Is there any relationship between bright color and exposure of the plant?
5. How many were observed feeding?
6. How many fed on other visitors?
7. What food has the plant to offer? Could all visitors reach it?
8. How many visitors carried away pollen?
9. Did each visitor seem to know what it was after and how to reach it?
10. Were any flower structures or formations apparent obstacles to the visitors?
11. What permanent residents were within the flower?
12. Describe some plant mechanisms for excluding unwelcome visitors.
13. How do plants provide for the reception of welcome visitors?
14. How do plants depend on animals for dispersal?

Exercise LXIV

PLANT GALLS AND THEIR INHABITANTS

OBJECT: To become familiar with the formers of and inhabitants of plant galls.

DIRECTIONS: This study cannot be made in a single attempt. The student should collect galls of leaves and stems on all field trips.

These can be kept in boxes or moist jars and some emerging forms can be secured.

Make a cross-section and longitudinal section through the center of each of several kinds of larger galls. Note the chambers within and the inhabitants. The latter may be plant lice, ants, fly larvae, small spiders, hymenopterous larvae, etc. The gall former is not easily determined in all cases.

Galls are found on the twigs, stems, and leaves of many plants: oak, elm, poplar, willow, hickory, alder, maple, sumac, rose, goldenrod, blackberry, hawthorn, wild cherry, dogwood, ash, and numerous other plants.

Galls are most easily preserved in formaldehyde for the permanent collection.

Classify all of the galls collected and suggest the causative organism. Identifications can be made by using the references listed in the text.

REPORT

1. What animals produce galls?
2. Does each gall have a single inhabitant?
3. Classify the inhabitants according to: former, guest, parasite.
4. How would you define a gall?
5. Are galls of any commercial importance? How?
6. What is the status of the various inhabitants of a plant gall?

Exercise LXV

THE STUDY OF TREES

OBJECT: To determine the identities, uses, and habits of native trees.

DIRECTIONS:

I. Comparison of a deciduous tree and an evergreen. Examine a maple tree (any kind), a buckeye, plane tree, or other

species. Note its outline or silhouette. Are any of the branches ascending? Descending? How are they arranged? Note the bark. Is it fissured? How? Compare the bark on the main trunk with that on the twigs and branches. Is the trunk divided? At what height does the main trunk begin to branch or deliquesce? Are the branches few or many? Are the leaves broad and flat? Lobed? How are the veins arranged? Is the margin toothed, wavy, or serrated? Is the stem of the leaf (petiole) long or short? Is it round, laterally flattened, or otherwise characteristic? Is there a difference in color between the face and the back of the leaf? Are the leaves opposite, alternate, or whorled? Does the twig bear prominent leaf scars? Describe the flowers and fruit if either are present.

Examine a pine, hemlock, and spruce. What is the shape or outline? How are the branches arranged? Does the trunk or stem extend to the top of the tree or is it divided into several or more upper branches? Is the bark fissured or scaly? Is there an exudation from wounds? Are the leaves short or long? Pointed or blunt? Triangular in cross-section or round? Are the leaves single or in clusters? Do they have petioles? Are they veined? How are the leaves arranged on the branches? Is the cone or fruit on the tree? On the ground? Examine the cone and seeds. Are the seeds naked or enclosed? Are they winged?

Compare the maple and a pine with other known trees. Which ones have deliquescent and which have excurrent stems or trunks?

II. Using a key to the families of trees, read it carefully and make a list of terms which you do not understand. Look up the meanings of these terms and then use the key to trace the identities of several trees which you already know. This will definitely familiarize you with the use of the key.

Select a section of the campus or a street and make a map of it, showing landmarks such as buildings, poles, fire hydrants, etc. Using the key, identify all trees in the mapped area and indicate their positions on the map. A legend can be constructed to locate

the positions and identities of all trees present. The trees can be indicated by circles on the map and each species can be given a number. The number can be placed in the circles on the map. The area should include twenty or more species, if possible.

III. Each species should be described in brief, concise language with the outstanding characters of shape, bark, leaves, etc., included. The form or outline should be sketched and a leaf or leaf print together with flowers, fruit, and the drawing of a twig should be included when possible.

IV. The following information should be prepared during the period devoted to tree study. Additional lists are included in the chapter on trees in *The Living World.*

1. Use of woods
2. Industries associated with forest areas
3. Agents of destruction
4. Economic and esthetic values of trees
5. Trees with: showy flowers, winged or tufted seeds, edible fruits, conspicuous bark
6. Paper making